ECOLOGY AND MANAGEMENT OF SOUTHWESTERN SEMIDESERT GRASS-SHRUB RANGES:
The Status of Our Knowledge

S. Clark Martin

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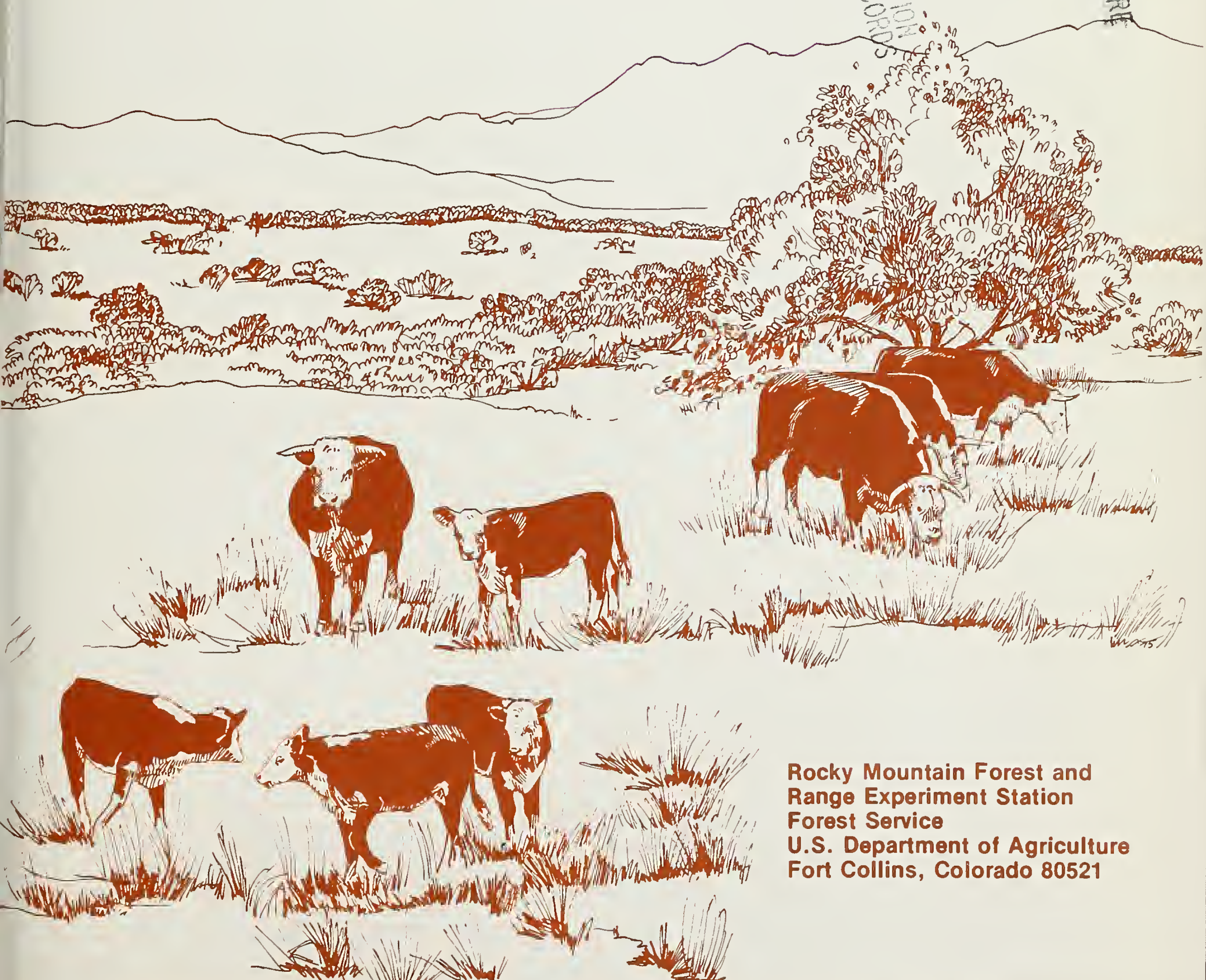

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Abstract

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The vegetation on much southwestern semidesert range has shifted from grassland to brush since livestock ranching began back 100 years ago. Shrub control, reseeding, and improved grazing management have reversed the downward trend on some ranges but most ranges are producing below their potential. Grazing will continue to be a major use for semidesert range despite high land prices and increased recreational activity from an expanding urban population. The role of ranges in meat production will become more important as increased population requires that arable lands be used mainly for food production. Additional research needs include the evaluation of: improved grazing systems, prescribed burning, and impacts of range improvement practices on wildlife, scenic beauty and other recreational attributes.

Keywords: Semidesert range, grazing system, plant control, multiple use.

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ERRATA

Page 7 - Paragraph 5, line 5 should read:
...the impact of unwise grazing was "Stock eat the...

Page 15 - Paragraph 4, No. 7 of "Grazing schedules that have not been noticeably superior to yearlong grazing..." should read:
7. Rest July through October--graze November through February--then rest March through June; 1 year in 2.

Page 30 - Paragraph 2 of Summary, line 2 should read:
...priority for continued research in increasing range usability is relatively low.

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ECOLOGY AND MANAGEMENT OF SOUTHWESTERN SEMIDESERT GRASS-SHRUB RANGES:
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INTRODUCTION

Southwestern grass-shrub ranges have supported a viable livestock industry for well over a hundred years. Livestock production has progressed from the boom and bust days of the open range, when drought periodically reduced the numbers of both animals and ranchers, to the relatively stable situation now provided by ranch boundaries and clearly defined property rights. Meanwhile the art and science of range management has also progressed. The primary concern no longer is simply to harvest the forage. Rather, emphasis is now placed on developing and maintaining the most productive stand of forage and grazing it in a manner that insures continued high production without detriment to other land uses. This publication summarizes the results of research and experience from many sources. Literature citations are provided for those who need more detailed information. The purpose in preparing this report has been to provide ranchers and range administrators with a brief statement of what is now known about the ecology and management of semidesert grass-shrub ranges, and to point out a few of the obvious gaps in existing knowledge.

Southwestern semidesert grass-shrub vegetation occupies a strip 50 to 100 miles wide along the southern boundaries of Arizona, New Mexico, and west Texas. Generally, it is a sparsely populated region of open spaces where most of the land is devoted to range livestock production.

PHYSICAL CHARACTERISTICS

Climate

The climate of the semidesert region is characterized by mild and open winters, and warm to hot summers. Relative humidities are low throughout the year except during storm periods. Average annual precipitation ranges from about 8 inches at its western edge west of Tucson to around 20 inches in areas adjacent to mountain ranges in southeastern Arizona and at the eastern edge of the region in west Texas (fig. 1). At least half of the area receives less than 10 inches precipitation per year.

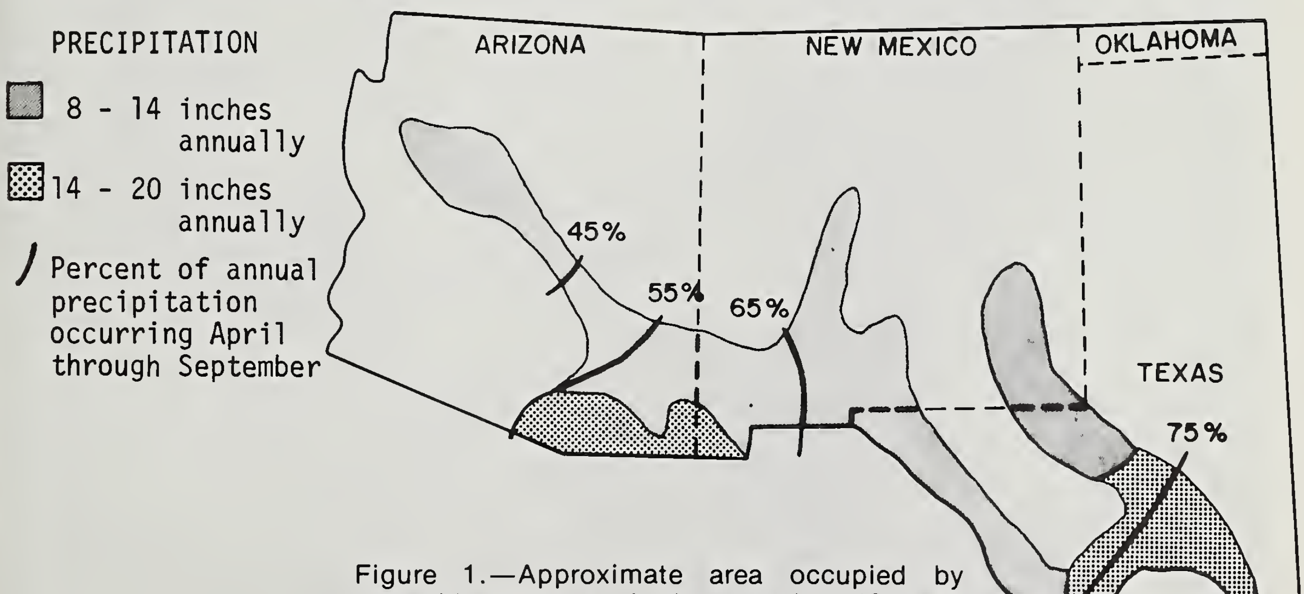


Figure 1.—Approximate area occupied by semidesert grass-shrub vegetation. (General precipitation characteristics for Arizona and New Mexico adapted from Dorroh 1946; those for Texas from Hambidge 1941.)

Sources of moisture for precipitation are the Pacific Ocean and the Gulf of Mexico. Moisture from the Pacific normally comes to the area during the winter months, and that from the Gulf during the summer, so there are two distinct rainy periods. Proximity to the source of moisture has an evident bearing on the seasonal distribution of rainfall. At Yuma, the point nearest the Pacific, less than 45 percent of the yearly rainfall comes during the April-to-September period, whereas almost 75 percent of the yearly rainfall comes during this period in the Big Bend area of Texas, near the Gulf of Mexico.

A major difference in precipitation distribution from the standpoint of grass production is the amount of rain in April, May, and June. At Tucson, Arizona, for example, no effective rain is expected in May and June. Here the summer monsoon begins around mid-July, although scattered thundershowers normally precede the onset of effective summer rains. In eastern New Mexico and west Texas, however, precipitation may begin in late April, and effective rainfall is expected in May and June. Hambidge (1941) shows that only 8 percent of the annual rainfall at Tucson comes in April, May, and June compared to 31 percent at Sonora, Texas. These differences in seasonal distribution of precipitation bear significantly on plant growth and must be recognized in designing grazing systems.

Geology and Soils

Most semidesert range ecosystems in the Southwest are relatively flat, and from 3,000 to 5,000 feet in elevation. The otherwise gentle terrain is interrupted by mountain ranges that rise abruptly to elevations of 9,000 feet or more.

Soils are typically those of the semidesert. The Mesa and Upland soils of the black grama community are light, shallow, and usually 12 inches or less in depth and frequently underlain by caliche. The mixed grama and mesquite grassland types occur on a wide variety of soils. Creosotebush usually is associated with calcareous soils, and is often underlain by caliche. It is also found in valley fills and other deep soils of alluvial origin.

The more common semidesert grasses and shrubs thrive on a variety of conditions of topography and soil. Still, the importance of these factors in vegeta-

Figure 2.—Black grama range in southern New Mexico. Associated plants are mesa dropseed, snakeweed, and soaptree yucca.

tion development is evidenced by numerous examples in which a sharp vegetation change delineates a change in soil or slope. Generally speaking, the basic causes have not been worked out for even the most striking soil-related vegetation differences, much less for the myriads of more subtle differences that undoubtedly exist.

BIOLOGICAL CHARACTERISTICS

Plant Communities

Grass-shrub communities occupy extensive acreages in the Southwest between 3,000 and 5,000 feet elevation. The perennial vegetation below about 3,000 feet consists mainly of desert shrubs, dominated in many places by creosotebush.[2] Above about 5,000 feet the grass-shrub type gives way to chaparral, pinyon-juniper or oak woodland, or occasionally to grassland. The forage supply consists mainly of perennial grasses, but browse species and annual grasses are sometimes important.

[2]Common and botanical names of plants mentioned are listed at the end of this paper. Nomenclature follows Kearney and Peebles (1951).

The vegetation of the semidesert has been classified in various ways. Kuchler (1964) includes the following vegetation types in the area: Mesquite bosques, creosotebush, creosotebush-tarbush, grama-tobosa, shrubsteppe, and transpecos shrub savanna. Lowe (1964) includes most of the area in the southwestern desertscrub and desert grassland formations. The semidesert includes such ecological groupings as "mesquite grass" (Shantz and Zon 1936), "desert plains" (Weaver and Clements 1938), "desert grass" (Nichol 1952), "mesquite-grasslands" or "mesquite-half-shrub" (Darrow 1944), and "desert grassland" (Humphrey 1958).

The major vegetational communities include the black grama grassland of New Mexico and west Texas (fig. 2), the flood plains or flats of tobosa, sacaton, or alkali sacaton that occur along watercourses (fig. 3), the mixed grama grasslands (fig. 4), the mesquite-infested grasslands (fig. 5), the widespread creosotebush stands (fig. 6), and the tarbush, whitethorn, creosotebush areas of adjoining and included portions of the Chihuahuan desert (fig. 7).

Figure 3.—Tobosa grass range characteristic of southern Arizona, New Mexico, and west Texas.

Figure 4.—Mixed grama range in southern Arizona. Dominant species are the short gramas (blue, hairy, and sprucetop) together with curly mesquite and threeawns.

Figure 5.—Mesquite-infested grasslands:
A, light stand of invading mesquite on southern Arizona grassland;

B, former black grama range in New Mexico now occupied by dune-type mesquite.

Figure 6.—Typical creosotebush stand in southern Arizona. Such stands support almost no herbaceous vegetation.

Figure 7.—Mixture of tarbush, whitethorn, and creosotebush, a typical chihuahuan desert mixture, in southeastern Arizona. (Univ. Ariz. photo.)

Precipitation and Plant Growth

Perennial grasses are the most reliable source of forage on semidesert ranges. These grasses grow whenever moisture is available and temperatures are favorable. In southern Arizona the summer rainy period, July, August, and the early part of September, produces about 90 percent of the year's herbage (Culley 1943). Growth in March and April from winter and early spring precipitation produces only a small amount of herbage. Grasses usually are dormant in May and June due to seasonal drought. Farther east, in New Mexico and Texas, rains in April, May, and June usually produce substantial forage.

In south-central New Mexico, Nelson (1934) observed that black grama increased or decreased from one fall to the next depending on the vigor of the plant at the start of the current season, and that current-season vigor was related to rainfall during the previous year or summer. Also, Lister and Schumacher (1937) found that the most beneficial precipitation distribution for black and Rothrock gramas was a relatively dry winter between wet autumns and springs. Paulsen and Ares (1962) reported that the basal area of perennial grasses in the fall correlated best with precipitation for the 15-month period ending September 30 of the year of measurement.

More recent studies in southern Arizona have shown that herbage production in a given summer is related not only to current summer rainfall, but to rainfall during previous growing periods (Cable 1975). The reason is that the culms that produce herbage during the current summer originated as basal buds that broke dormancy either during the preceding spring, or more commonly, the preceding fall. Consequently, if a dry summer and a dry spring precede a summer of high rainfall, herbage production will be relatively low because the number of

herbage-producing culms is low. On the other hand, two good rainfall summers in succession, or a good rainfall summer preceded by an exceptional spring, can be expected to produce high forage yields. Ground cover of perennial grasses likewise increases mainly after two consecutive good growth periods. A wet fall, or a wet winter and spring, activates basal buds and enlarges individual plants. The practical implication of this phenomenon is that it takes 2 years to produce a grass crop. Grazing systems based on the assumption that each year's forage production is an independent event simply do not fit the situation.

Grazing and Vegetation Change

The entire semidesert region has changed in the last 100 years. Griffiths (1901) cited testimony of ranchers as to the decline in range forage production and increases in gully erosion. Grazing by domestic animals has generally reduced the abundance and production of preferred forage grasses. In many places these preferred forage plants have been replaced in some degree by less desirable plants. The vegetation of ranges that have been most severely grazed is usually dominated by plants that are not palatable to livestock. Shrubs, unpalatable forbs, and annual grasses or short-lived perennial grasses are characteristic of ranges that have suffered past abuse. Conversely, ranges that support a vigorous stand of native perennial grasses, particularly those with a high percentage of midgrasses, are considered to be in reasonably good condition.

The condition of many ranges has been depressed so long that no standard of potential is available. Other ranges have improved greatly during the last three or four decades. Still, semidesert ranges that are in uniformly good to excellent condition are exceptional. Generally speaking, ranges with the lowest potential are in the worst condition. Many ranges that are in generally good condition also include spots where productivity is far below potential.

The most widespread, general manifestation of range deterioration is an increase in shrubby vegetation. Mesquite, creosotebush, pricklypear and cholla cacti, burroweed, snakeweed, and various acacias have replaced grasses on much of the area (fig. 8). Invasions by these species usually have been accompanied by decreased herbage production as well as by substantial increases in sheet and gully erosion.

Figure 8.—As shrubs replace grasses, the range deteriorates:

A, in 1922 this spot at the edge of a mesquite stand had a good grass cover and few woody plants;

B, by 1935 burroweed, cholla, and new mesquites had almost replaced the grasses.

SOCIAL AND ECONOMIC FACTORS

Historical Development

The historical development of the western portion of the semidesert grass-shrub region is portrayed by Hastings and Turner (1965). They present the view that, even at the time cattlemen from the "East" occupied the region, conditions were not those of a stable, pristine climax of indefinite age. The Texas longhorns moved in only after the Indians, Spaniards, and Mexicans had left their imprints on the land.

Populations of Indians and native herbivores apparently waxed and waned in prehistoric times primarily in response to climatic factors. Cattle were introduced into southern Arizona soon after 1700 by Father Kino. Northern Mexico was probably fully stocked by cattle on Spanish ranches during the last quarter of the 18th century. Expansion of these Spanish ranching operations to the north probably reached its peak in southern Arizona in the 1820's and 1830's. Nearly all of the ranches established during this time were abandoned by 1846, leaving many cattle to run wild.

The number of cattle in the Arizona territory was reportedly only 5,000 in 1870. Rapid movements of cattle from Texas and Sonora into Arizona increased to an estimated 650,000 in 1885. The census of 1890 shows 1,095,000 range cattle in Arizona. By this time, many cattlemen realized that the ranges were overstocked. Following severe summer drought in 1891 and 1892, cattle losses from starvation were estimated to be from 50 to 75 percent by the late spring of 1893.

Hastings and Turner (1965) place the date for the beginning of the current arroyo cutting cycle in the Southwest, and for the initiation of dramatic changes in vegetation, at about 1890. They cite other reports to the effect that there have been earlier cycles of arroyo cutting, and argue that a warming and drying climatic trend from about 1875 to 1890 was a major factor contributing to this one. That the buildup of cattle numbers in the 1880's was a strong contributing factor is unquestioned. Whether the shift to aridity postulated by Hastings and Turner would have led to the dramatic change in vegetation and arroyo channel characteristics without grazing is uncertain.

Soon after the turn of the century, Wooton (1908), reporting on the condition of New Mexico ranges, stated that the range was run down and not as productive as it once was. Wooton's explanation of the impact on unwise grazing was "Stock eat the valuable forage plants and leave the poor ones, thus giving the latter undue advantages in the struggle for existence." . . . "Skinned ranges do not hold water; the runoff is greater and more rapid, tending to increase dryness, the cutting away of soil, and the drying up of springs and watercourses." Wooton attributed the poor condition of the range largely to the open range policy. He estimated the carrying capacity of the semidesert grass-shrub type to be 50 acres or more per head per year. Jardine and Hurtt (1917) estimated that the carrying capacity of the Jornada Experimental Range was 38 acres per head per year, and that the carrying capacity of outside range was about 50 acres.

In southern Arizona, Griffiths (1901) likewise found the ranges to be seriously depleted as a result of serious and prolonged overstocking due to the free range policy. He felt that the ranges might be improved by appropriate rest, but that in some cases seeding might be worthwhile or necessary. Three years later, he estimated that the carrying capacity of lands in Arizona ranged from 52 to 100 acres per cow (Griffiths 1904). In 1910, reporting changes on the Santa Rita Experimental Range (established in 1903), Griffiths felt that 3 years of rest apparently was sufficient to restore the range; that the best ranges on the Santa Rita might carry one animal per 20 acres; but that such areas were very limited.

Griffiths (1910) also reported a dramatic increase in mesquite, particularly at the upper elevations, and attributed the increase to protection from fire. By 1941 many acres of former grassland were fully occupied by mesquite (fig. 9). Griffiths (1910) reported that filaree was the only introduced plant that succeeded in seeding trials, and that the best way to improve the range was by proper protection from overgrazing. In Texas, Jared Smith (1899) after analyzing the opinions of 302 stockmen in 115 counties, estimated the average decrease in carrying capacity to be 40 percent in 82 counties; 19 counties reported improvement. Smith agreed with other writers in blaming the free-range policy for most of the decline. Too many cattle, the result of free-range policy, was also blamed by Thornber (1910) for the poor condition of Arizona ranges at that time.

Passage of the Taylor Grazing Act in 1934 brought 10,400,000 acres of semidesert grassland and 7,954,000 acres of southern desert shrub under federal supervision. The Taylor Grazing Act applied to all unallocated public domain. It provided for assignment of the land to individual stockmen, but did not include a strong administrative organization or adequate financing.

Current Situation

Many semidesert ranges have improved since the 1930's. Moderate stocking is more common, and many ranchers have improved their ranges by seeding, controlling shrubs, or periodic rest. Research results are publicized and put into practice

Figure 9.—Mesquite invasion in southern Arizona:

A, Griffiths photo in 1903 shows only widely scattered small mesquites.

B, repeat photo in 1941 shows a well developed mesquite stand.

through cooperative programs of the Soil Conservation Service, Forest Service, Bureau of Land Management, and Cooperative Extension Service, and through participation by ranchers in the Society for Range Management. Still, much of the semidesert grass-shrub range is producing far less than it could (fig. 10).

Semidesert ranges no longer are the almost exclusive province of ranches, range researchers, and public land administrators. Absentee owners, speculators, miners, sportsmen, and other recreationists are claiming an increasing voice in what happens on the land. Public concern about esthetics, habitat destruction, or the balance of nature has at times been great enough to halt projects to control shrubs or predators. Widespread concern about how public lands are managed has greatly increased planning costs of public land administration. To some extent it limits management choices for private landholders as well. As Byerly (1970) has indicated, we must now solve the problems of agricultural production with methods that are socially and economically acceptable. Environmental impact statements must now be included in proposals for major projects. Maximum sustained production of forage and livestock no longer is an adequate and complete range management objective.

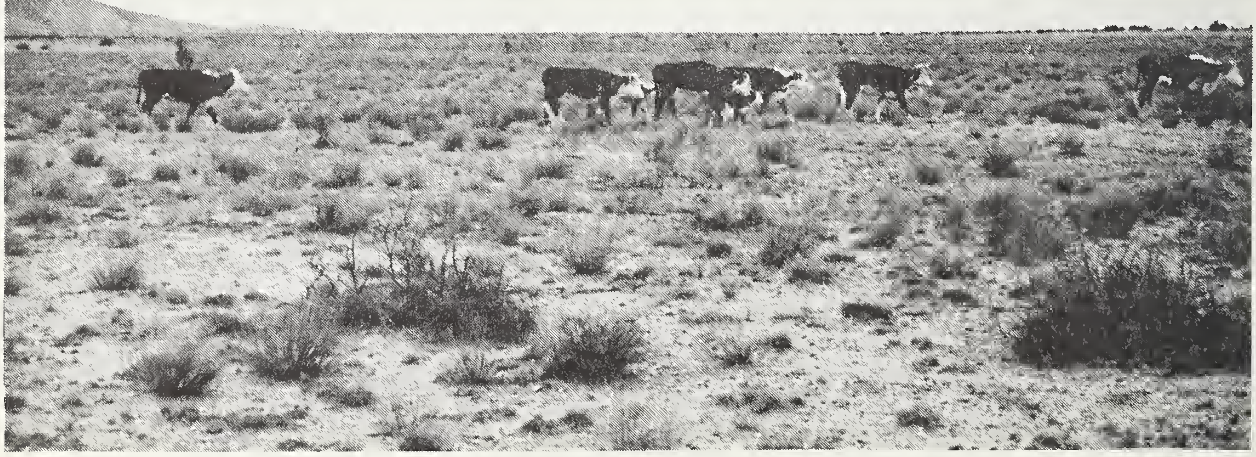


Figure 10.—This black grama range is producing far below potential. The black grama had been largely replaced by threeawns, mesquite, snakeweed, and annuals. Usable forage production here could at least be doubled.

Ranch Operations

The economics of ranching are changing greatly. Mont Saunderson (1939) reported the investment in land per animal unit to be from $71 to $108. Now we are in a land boom. A 1975 advertisement in the New Mexico Stockman listed ranches from $600 to $1,100 per animal unit. Gray (1970) reported investment per animal unit in ranches in the central mountains of New Mexico to be around $1,200. Ranch income has not increased correspondingly, however.

Except for 1972 and 1973,[3] prices for ranches and cattle in recent years have been such that net return to capital and management for Arizona cattle ranches was very low or even negative (Smith and Martin 1970). Frank Boice (1967) stated that a cow could not service a debt load much over $250. Why, then are ranches bought at $1,200 per animal unit? Andrews and Luden (1965) suggest that many purchases of rangeland are for purposes other than livestock production. Sargent (1957) listed 10 motives for owning ranch or farmland, and found that those who purchased land for motives other than agricultural production were in a stronger financial position than the rancher. William Martin (1966) has hypothesized that high ranch prices apparently are not based on the profit motive. Rather, ranch purchasers are simply paying for the privilege of being ranchers.

The future market in ranchland is uncertain. Smith and Martin (1970) report that a high percentage of Arizona ranchers are nearing retirement age. This means that large numbers of ranches will be coming on the market in the next 10 years or so. Only time will tell whether buyers will be plentiful enough and prosperous enough to maintain current prices. Meanwhile, the most economical way for ranchers to increase their livestock operations may be to increase forage production on the land they already have. Mesquite control, for example, can in many cases provide forage for additional cows at a cost of $200 to $300 per animal unit. Seeding and improved grazing systems are additional possibilities.

Despite the rather dismal economic status of ranching in recent decades, there seems little reason to believe that cattle ranching will cease or be greatly diminished anytime soon. No matter who owns or uses these grazing lands, cattle will continue to be a major source of regular income.

Energy Relations

Ours is an era of expressed concern about the energy requirements necessary to maintain our way of life. Agriculture has replaced the horse with the tractor, thereby making more food and fiber available for human consumption. The cost of this conversion, however, is that we now spend 10,000 calories of fossil fuel energy to produce 3,000 calories in crop products (Thomas 1971). Beef produced on the range, however, is derived almost entirely from solar energy. Fossil fuel expenditure is limited to that required to operate the rancher's car or pickup, that required by the farmer to grow supplemental feeds used by the rancher, and the relatively small amount that is used from time to time in the form of fuel for tractors or airplanes used to control brush, build ponds, or seed the range. Ecologically, range livestock production is more nearly in balance with nature than is mechanized agriculture.

[3] *Higher cattle prices in 1972 and 1973 greatly increased ranch income in those years, but cattle prices in 1974 dropped below the 1968-71 level.*

RANGE MANAGEMENT PRACTICES

Perennial grasses provide the most important forage on grass-shrub ranges. Management therefore should be aimed at maintaining vigorous, productive grass stands. The objectives should be to increase good forage species and eliminate competing nonforage plants. Since forage production is more severely limited by lack of moisture than by any other single factor, every effort must be made to conserve and use as much moisture as possible on the site. A dense, well-dispersed stand of perennial grasses is the most effective kind of vegetation for utilizing available soil moisture before it evaporates following each rain.

Palatable shrubs and forbs contribute materially to the diets of animals on many semidesert ranges. Many of the forbs are annuals that provide high-quality forage for a brief time either during the spring or summer growing seasons. Shrubs provide relatively high-quality forage in winter or during dry periods when grass herbage is dry and frequently is deficient in essential nutrients. Generally speaking, cattle on ranges with a mixture of palatable shrubs and grasses require less supplementation in winter than do cattle on shrub-free grasslands. On ranges where wildlife is important, shrubs provide cover as well as forage, and management practices must meet the needs of shrubs as well as grasses.

Grass species vary greatly in palatability, and cattle tend to select and graze the preferred species closely. These plants lose vigor and die from excessive grazing and are replaced by species that are less palatable and/or more resistant to grazing. On the Santa Rita Experimental Range in Arizona, for example, species favored by moderate to light grazing include Arizona cottontop, bush muhly, black grama, sideoats grama, tall threeawns, and such less-abundant species as plains lovegrass and green sprangletop. On the other hand, species that

are most abundant under continuous heavy grazing are curly mesquite, Rothrock grama, and slender grama.

Obtaining Proper Grazing Use

Kind of Animal

Semidesert ranges are grazed primarily by cattle. At the eastern end of the semidesert area, sheep and/or goats are somtimes run with cattle to better utilize all classes of forage. There is substantial evidence from Merrill's (1954) work at Sonora, Texas, that sheep help keep the forbs in check, and goats help keep the shrub live oak and other relatively palatable shrubs from getting out of hand. Vegetation control exerted by sheep and goats therefore is a fringe benefit over and above the income from animal products. There is little evidence to suggest, however, that browsing by sheep or goats will materially reduce the growth and spread of mesquite, juniper, catclaw acacia, or creosotebush.

It appears that cattle are better suited than sheep or goats for most semidesert range. They require less attention, and compete less directly with wildlife for forage.

Additional information on the suitability of different kinds or classes of animals for semidesert range is desirable, but the need is not critical or urgent.

Number of Animals

The key indicator of proper stocking is the intensity of use. As a rule of thumb, the number of cattle grazed should be sufficient to utilize about 40 percent of the perennial grass herbage produced in an average year. This level of grazing will maintain good grass composition over most of the range. Even at this average level of use the vegetation where cattle naturally congregate will be grazed more closely than is ideal, but severely overgrazed spots will be relatively small. Estimated average yearlong stocking rates (table 1) were developed on the Santa Rita Experimental Range by Reynolds and Martin (1968). These rates apply fairly well to the entire spectrum of southwestern ranges and range conditions. They range from 13 to 2 acres per animal unit month. These are average figures over a period of years assuming yearlong grazing. The poorer ranges vary the most from year to year. In poor years they may produce no herbaceous forage.

The stocking rates above assume that utilization of perennial grasses over a period of years averages around 40 percent, but may range from as low as 20 percent to as high as 60 percent in individual years. A simple, practical, and inexpensive method for measuring utilization is to determine the percentage of grazed and ungrazed plants (Roach 1950). The relationship between percentage of herbage removed and number of plants ungrazed (fig. 11) is for mixed species of perennial grasses on the Santa Rita Experimental Range. The relationship varies somewhat among species, but unless great precision is needed it is suitable for most applications. As a rule of thumb, about half of the perennial grass plants should remain ungrazed in the average year (fig. 12).

For various reasons, ranchers are tempted to stock on the heavy side of proper. First, perhaps, is the factor of attitude or image. The rancher views himself as a cattleman—his standing among cattlemen and his self esteem are based to a degree on

Table 1.--Estimated average yearlong stocking rate, by condition class, for semidesert grass-shrub range (adapted from Reynolds and Martin 1968)

Elevation (Feet)	Precipitation	Range condition class: Very poor[1]		Poor and fair		Good and excellent	
	Inches	*Animals/ square mile*	*Acres/ animal*	*Animals/ square mile*	*Acres/ animal*	*Animals/ square mile*	*Acres/ animal*
High (4,000-5,000)	16+	<12	>50	15-18	35- 45	18-25	25- 35
Intermediate (3,300-4,000)	12-16	<6	>100	6-12	50-100	12-16	40- 50
Low (Less than 3,300)	<12	<4	>160	4- 6	100-160	6-10	60-100

[1] < signifies less than; > signifies more than.

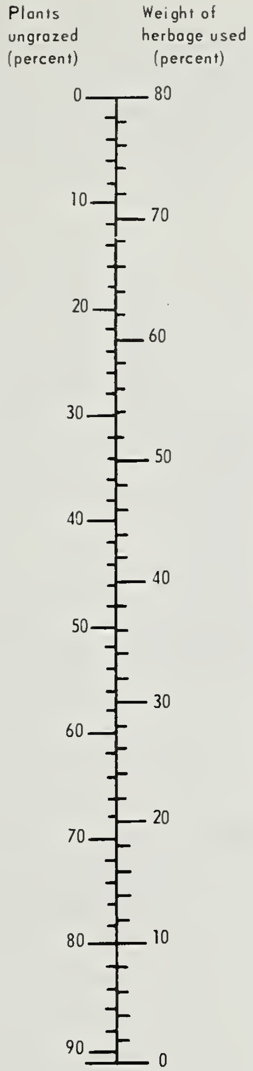


Figure 11.—Chart for approximating percent utilization by weight, when average percentage of ungrazed key species has been determined by survey.

the number of cattle he owns. Second, is the difficulty of determining capacity when forage production varies greatly from year to year. Third, in the short haul, a degree of overstocking almost always puts more money in the pocket. Up to a point, maximum ranch income in the short-run results from stocking rates that are too heavy for the good of the range because they produce greater gains per acre.

Remedies for some of these inclinations seem obvious. The image factor, for example, requires changing the rancher from a "cattleman" to a "forage grower," and demoting the cow to the status of forage harvester and processor. A competent forage grower will not maintain more harvesters than are needed to gather and process his crop.

Figure 12.—Example of properly used range: average use at the end of June following a year of average forage production where average annual rainfall is 16 inches.

The second difficulty is harder to resolve. The carrying capacity of a range cannot be measured precisely. Forage production varies greatly from year to year as well as seasonally (figs. 13, 14). Even the quantity of usable forage at a given time can only be estimated. And the responses of forage plants to grazing depend not only on when and how closely the plant is grazed, but on how vigorous the plant is at the time and on how favorable the climate for recovery turns out to be. The forage requirements for range livestock also vary seasonally and are not precisely known. So the problem is to arrive at a stocking plan that meets the long-range needs of both plants and animals without imposing undue temporary hardship on either.

A fact of life to be faced in the fall of a drought year in the western half of the semidesert range is that substantial forage growth is not to be expected before mid-July of the next year. Also, it should be recognized that forage production cannot be high in the first growing season after drought because high yield requires two successive favorable growing periods. For example, Nelson (1934) reported that black grama increased or decreased in accordance with rainfall for the previous year, and Cable (1975) found that herbage production was strongly influenced by late summer rainfall in the previous year. Since the first expected period of rapid forage growth is at least 8 to 10 months away, and there is less than a 50 percent chance that the next year's forage crop will be as good as average, the reasonable decision following a summer drought is to cull more severely than usual.

Figure 13.—On low-elevation, low-rainfall ranges where annual grasses prevail, production of grass herbage can drop from (**A**) 655 pounds per acre one year to (**B**) 3 pounds the next, then shoot up to (**C**) almost 900 pounds a year later.

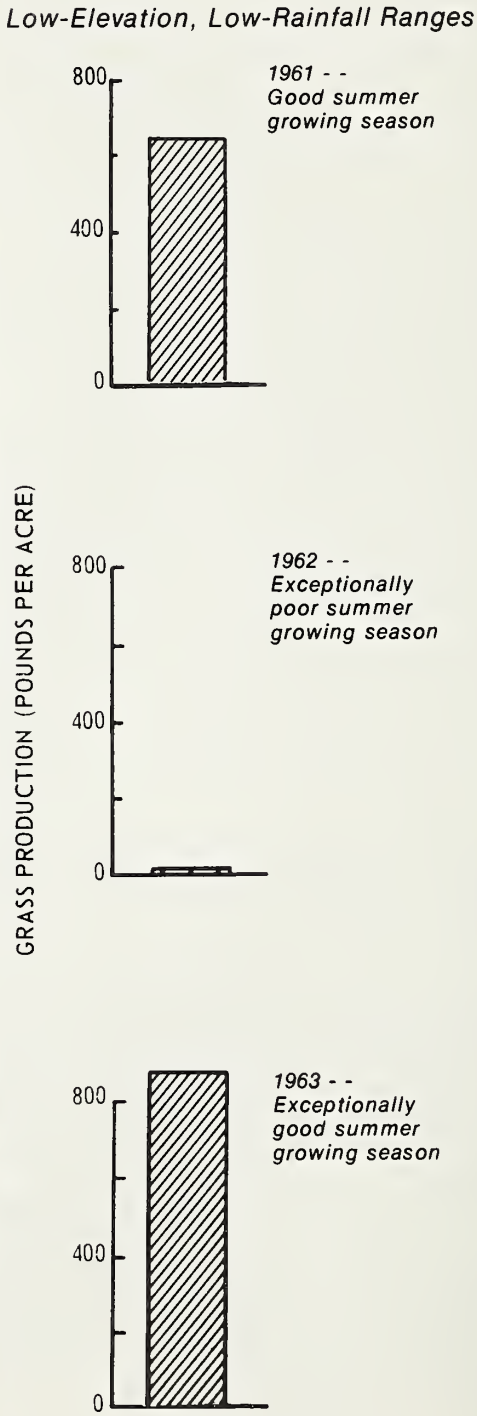
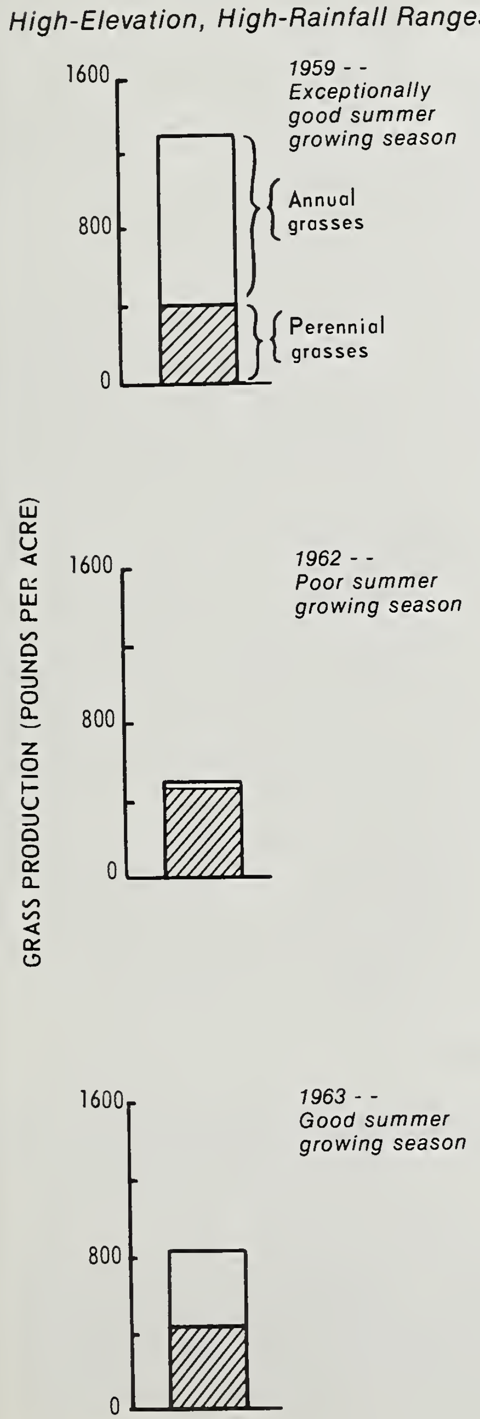


Figure 14.—On highly productive ranges, perennial grasses produce a modest yield of forage even in poor years. Annual grasses add substantially to the herbage supply only in years of moderate to high rainfall.



Nelson (1934) evaluated the impact of drought and grazing on black grama ranges in southern New Mexico. He found that the production of heavily overgrazed range declined 81 percent, compared with a decline of only 58 percent on conservatively grazed range.

There is some hope that usable formulas can be developed for estimating forage production from rainfall records. Cable (1975), for example, has found that perennial grass production in southern Arizona is strongly correlated with the product of certain portions of current and past summer rainfall. Perfection of such formulas would enable the rancher to estimate his forage crop with little effort and adjust animal numbers accordingly. Meanwhile, his best bet is to keep adjusting animal numbers until use on perennial grasses in an average year is about 40 percent. If this is done, the third problem—stocking too heavily in order to increase immediate income—will have been solved also.

Reliable procedures for determining appropriate stocking rates continue to be among the greatest needs of ranchers and public land administrators. This continues to be a problem of the highest priority. Aspects of the stocking rate problem that appear especially urgent are: (1) determining levels of stocking that leave the optimum amount of protective vegetation and litter, (2) determining appropriate intensities of use for systems of grazing other than continuous yearlong, and (3) identifying and evaluating beneficial effects of grazing.

Season of Grazing

Both the preferences of the cattle and the responses of plants must be considered in developing plans for seasonal grazing. Semidesert ranges traditionally have been grazed yearlong. Research and experience indicate that these ranges can be grazed at any time of year without serious detriment if the intensity of grazing is not too severe, and if periods of grazing alternate with suitable periods of rest.

On the Santa Rita Experimental Range, grazing November to February apparently has no detrimental effect, but either spring grazing (March to June) or summer grazing (July to October) can be detrimental if too severe or too frequent. During the summer rainy reason, perennial grasses grow rapidly enough to keep ahead of consumption if the stocking rate is moderate and rainfall is adequate. But favorite plants and preferred parts of the range are overgrazed and regrazed, even in average-to-good years. This kind of selective grazing is critical early in the spring when green forage is always scarce. It is during these periods of forage scarcity that selective grazing is most harmful.

Selective grazing is more serious on some ranges than on others. On flat ranges, for example, the tendency of cattle to graze off the last bite of grass near water before ranging farther is much less strong than on steep, rocky ranges. Kinds of forage make a difference too. For example, Cable and Martin (1975) found that the most influential factor affecting the percent of forage used at a given location was the relative palatability of the forage. These results were obtained within 1 mile of water on moderately sloping to rough ranges where the average annual rainfall is about 16 inches and the most common forage grasses are slender grama, sideoats grama, Arizona cottontop, tall threeawns, and black grama. Of these five major species, Arizona cottontop was the most palatable, black grama the least. Thus, yearlong grazing almost invariably results in excessive use of Arizona cottontop.

A different situation prevails in New Mexico on range dominated by black grama. Herbel et al. (1974) found that mesa dropseed and such forbs as leatherweed croton, woolly paperflower, spectaclepod, and Russianthistle would draw cattle out as far as 3 miles from water at certain times of the year, thereby taking some of the grazing pressure off the black grama. In this case there are times when black grama is less palatable than some of the forbs and short-lived grasses. When cattle switch to these alternate forages, black grama gets a break. The extent to which alternate forages reduce the need for planned rest on black grama range is uncertain.

Additional research is needed to find out how to reduce the detrimental effects of grazing in the spring and during summer drought. The greatest need in this area is for basic information on the responses of the most important semidesert perennial grasses to drought and grazing. Arizona cottontop, black grama, sideoats grama, blue grama, bush muhly, plains lovegrass, plains bristlegrass, tobosa, curly mesquite, tall threeawns, alkali sacaton, and sand dropseed are some of the candidates for this kind of research. Because such information is necessary to formulate sound grazing systems, this problem has high priority for research.

Grazing Systems

Yearlong grazing.—Continuous yearlong grazing is the most common system on semidesert ranges. The primary shortcoming of the method is that it leads to excessive use in areas of concentration and wasted forage where cattle rarely graze. It also leads to inequitable distribution of use among species with favorite species being grazed more closely and more often than those that are less palatable. Cool-season grasses and palatable shrubs are almost always grazed too closely. At a moderate stocking level, continuous yearlong grazing does not impose exces-

sive grazing over an entire pasture during the summer growing season because only one-fifth of the year's grazing takes place in a period that produces 90 percent of the forage (Culley 1943). The problem is that the favorite parts of the pasture and the favorite plants are grazed first each summer. Much more critical is the spring growth period, when 10 percent or less of the forage is produced but previously grazed plants are regrazed as cattle search out the new green forage.

Several alternatives to continuous yearlong grazing have been tried. Many reports show less weight gain from complex systems than from continuous grazing. In west Texas, however, Waldrip et al. (1967) reported that two- and four-pasture rotation systems produced more and heavier calves than did continuous use. A four-pasture three-herd system that rests the range 4 months out of 16 has also produced favorable responses in both plants and animals at Sonora, Texas (Merrill 1954).

Many, if not most, of the complex grazing systems also have failed to improve the range. Many failed because the rest periods were too short, too infrequent, or at the wrong time to allow plants to recover from grazing. Other systems failed because stocking was too heavy or because some other basic principle of range management was ignored.

In some circumstances, a degree of summer deferment can be achieved by closing access to waters. On the Santa Rita Experimental Range, this method reduced use near water but only if average use for the entire pasture did not exceed about 40 percent and if the water was closed during the summer growing season (Martin and Ward 1970).

Grazing schedules that have not been noticeably superior to yearlong grazing (Martin 1973, Martin and Cable 1974, Martin and Ward, in press) include:

1. Rest November through April each year.
2. Rest May through October each year.
3. Rest November through February; 1 year in 3, 2 years in 3, 3 years in 4, or every year.
4. Rest March through June; 1 year in 3, 1 year in 2, 2 years in 3, or 3 years in 4.
5. Rest July through October; 1 year in 3, 1 year in 2, 2 years in 3, or 3 years in 4.
6. Rest March through October; 1 year in 3 or 1 year in 2.
7. Rest March through October—graze November through February—then rest July through June; 1 year in 2.

Obviously there are many alternatives to yearlong grazing, but only those that meet the needs of forage plants will improve the range. Four of the more promising alternatives are described in the following paragraphs.

Rest rotation.—The rest rotation grazing system advocated by Hormay (1970) is a departure from conventional systems of deferment and rotation. Rather than dividing the grazing or growing season artificially into two, three, or more parts and moving livestock by the calendar, the rest rotation system provides rest for specific purposes and for longer periods than under the more conventional methods. Also, the rest rotation system assumes that heavy grazing in periods of forage scarcity can be tolerated if forage plants have ample rest periods for recovery. This assumption has not been fully validated, even though Mueggler (1972) suggests that occasional heavy grazing under rest rotation grazing may be beneficial. The classic rest rotation plan is a five-pasture system with rest periods designed after each grazing for one of the following purposes:

1. To allow plants to make and store food and recover vigor.
2. To allow seed to ripen.
3. To allow seedlings to become established.
4. To allow litter to accumulate between plants.

As in the deferred and rotation system (Sampson 1913), grazing after seed ripening is assumed to aid in the establishment of new seedlings by trampling seed into the ground for more effective germination. The main principles of rest rotation can be built into four- or three-pasture grazing systems. Hormay suggests that pastures should be of about equal capacity. Rest rotation systems undoubtedly will benefit many semidesert ranges if the grazing schedules are properly meshed with growth periods.

High-intensity low-frequency grazing.—A relatively new rotation scheme, high-intensity low-frequency grazing, is currently being tested in Texas. The concept is similar to that of "short duration grazing" described by Goodloe (1969). In this system, all cattle in a set of several pastures graze one pasture at a time. The system is less formal than the Hormay system in that pastures need not be of equal capacity, and cattle are not moved on a prescribed schedule to meet specific objectives. Cattle are left in a pasture until the desired degree of use is obtained, then are moved to another. Heavy stocking for a short period reportedly results in more even utilization of the forage both from place to place and among species. Consequently, the favored forage plants have a better chance than under systems where cattle have an opportunity to be more selective. Rapid recovery of forage plants is the result of relatively long rest periods between short grazing periods. The high-intensity low-frequency system reduces labor costs because the cattle are all in one pasture. It provides opportunities for range improvement through brush control or seeding without fencing the project area.

Santa Rita three-pasture rotation.—Another system, now being tested on the Santa Rita Experimental Range, rests each range two-thirds of the time. Each unit in a three-pasture set is rested March through October 2 years out of 3. Winter grazing (November to February) is scheduled between the two successive March-October rest periods. Trampling in winter may help plant seeds, and grazing off the old herbage may give seedlings of intolerant species a better chance to become established. This schedule provides 12 months of rest immediately before each period of spring-summer grazing, and is expected to reduce the intensity of grazing and regrazing on favorite plants in the spring. This system is based on results on small plots where rest March through October 2 years out of 3 increased the density of perennial grass near water without controlling utilization (Martin 1973).

Apparent advantages of the system are: (1) The cost of handling cattle is reduced because only one-third of the pastures are used at a time. (2) Each year's forage crop is used from each pasture. (3) It provides opportunities for seeding or shrub control without fencing off the project areas. (4) The quality and quantity of forage from July through October, the period when cattle most consistently make gains, should be adequate because 90 percent of the year's forage is produced in this period.

This system is more formal than the high-intensity low-frequency system previously described, but departure from the schedule is permitted. The herd normally is moved twice (November 1 and March 1), but if forage in the grazed pasture is inadequate, cattle are moved ahead of time to the pasture next scheduled for grazing. A forage shortage therefore speeds up the cycle, but the normal schedule is resumed as soon as possible. On the other hand, a forage surplus may permit an extra rest period and/or an opportunity for brush control or seeding.

Schmutz three-pasture rotation.—Another three-pasture one-herd system for semidesert ranges is proposed by Schmutz (1973). In this system the year is divided into the same three 4-month periods: March-June, July-October, and November-February. A pasture is grazed July through October in its first year, March through June in its second year, and November through February in its third year. It differs from the system under test at the Santa Rita in that (1) no pasture is grazed continuously March through October, (2) 16 months' rest after summer grazing and 4 months' rest after winter or spring grazing is provided, and (3) the herd is moved three times a year (November 1, March 1, and July 1). This system deserves field evaluation.

Discussion.—Many ranchers are reluctant to change from yearlong grazing to a more complex system because they are not sure that the change will pay. On many ranges, for example, lack of water is an obstacle that must be overcome before complex grazing systems can be installed. If a pasture is watered by a spring or well that is barely adequate for the number of livestock the range will support on a yearlong basis, additional water must be developed before the pasture can be used in a system that requires doubling or tripling the stocking for a shorter period. Fences may have to be moved or new division fences built. Grazing systems also require extra cattle moves. Appropriate rotation systems offer compensating benefits, however, such as lower livestock handling costs that result from having cattle concentrated. They also offer the best insurance against future declines in range productivity.

Experience shows that complex grazing systems, even if well designed, do not always produce dramatic range improvement. Sampson (1951) concluded that regional and local conditions greatly influenced results from grazing systems, and that some form of rotational grazing was essential for bunchgrass ranges. Moderate seasonlong grazing produced greater livestock gains on sod-grass ranges without apparent injury to the vegetation, however.

A major difference between bunchgrass and sod-grass ranges is the way the forage stands are perpetuated. Bunchgrass ranges are maintained only if new plants become established fast enough to replace those that die. Sod-grass ranges perpetuate themselves vegetatively. Periodic rest to allow for seed production and establishment of seedlings is therefore a more evident need for bunchgrass ranges. These differences lead to arguments as to the importance of such factors as deferment until seed maturity and the role of grazing and trampling in planting grass seed.

A benefit that grazing systems offer on all types of range is periodic rest for overgrazed areas and overgrazed species. In the long run, this may outweigh the short-run advantage in animal gains that are so frequently reported for continuous grazing.

Finally, climatic events can override the effects of any grazing treatment. Severe and prolonged drought can temporarily reduce perennial grass stands under any grazing system. However, systems of grazing that meet the growth requirements of forage plants reduce the impact of drought on perennial grasses, and increase the rate of recovery afterwards. Improvement in perennial grass stands can be rapid, but rapid increases come only when the amount and distribution of rainfall is favorable. Generally speaking, two summers of average or above rainfall in succession are required for dramatic improvement in perennial grass stands.

Summary.—Effective grazing systems require resting each part of the range a substantial part (as much as two-thirds) of the time. Rest periods not

only must meet the growth requirements of important forage plants, but must also offset the natural tendency of cattle to regraze their favorite plants. Thus a major reason for rest periods on semidesert range is to even out utilization from place to place and among species. Systems must be designed to meet the needs of plants without unduly neglecting the animal's persistent need for ample high-quality forage. Four systems that appear to meet these specifications are: (1) rest rotation grazing, (2) high-intensity low-frequency grazing, (3) the Santa Rita three-pasture rotation, and (4) the Schmutz three-pasture rotation.

Additional research on grazing systems is urgently needed. Good systems, which could permit range improvement without severe reductions in cattle numbers, would remove a major barrier to range improvement. The first priority for research in this area is to pilot test promising systems such as those listed above. A test of system "3" is in progress on the Santa Rita Experimental Range. Tests on other forage types and conditions are needed.

Factors Affecting Forage Production

Rainfall

Herbage production of perennial grasses on a given range unit varies greatly from year to year, depending on the amount and distribution of rainfall. Herbel[4] reports yields as high as 800 pounds per acre on upland sites and 3,500 pounds per acre on flood plain sites in New Mexico where average rainfall is only 9 inches. In the 10- to 12-inch rainfall zone in southern Arizona, average herbage production of annual and perennial grasses combined over an entire pasture may range from as little as 5 pounds per acre in a dry year to 250 pounds in favorable years (fig. 15). Where rainfall and growing conditions are better, the year-to-year range in production may be from 300 to 1,200 pounds per acre (fig. 16). Over a period of years, however, average summer rainfall strongly affects the density and species composition of perennial grass stands, and thereby establishes the average productivity level. On the Santa Rita Experimental Range, where average summer rainfall from 1954 to 1968 ranged from 7.4 inches in the driest pasture to 10.8 on the wettest, average perennial grass yields ranged from 17 to 498 pounds per acre, respectively. Differences in average summer rainfall account for 86 percent of the average difference among units in perennial grass yields. On the average, each inch of average summer rainfall increased perennial grass production about 134 pounds per acre (fig. 17).

On a given site, the yield of annual grasses in different years is strongly and positively related to the amount of summer rainfall. On the other hand, ranges with higher average rainfall may produce less annual grass than low rainfall ranges. On the 16 Santa Rita pastures, for example, the average yield of annual grasses from 1954 to 1968 was less with 11.4 inches summer rainfall than with 7.4 inches. Differences in average summer rainfall accounted for only 2 percent of the differences among sites in production of annual grasses. Average yields of annual grasses apparently are more strongly affected by differences in the amount of competing perennial vegetation than by differences in average rainfall.

[4]*Personal communication from Carlton H. Herbel, January 28, 1975.*

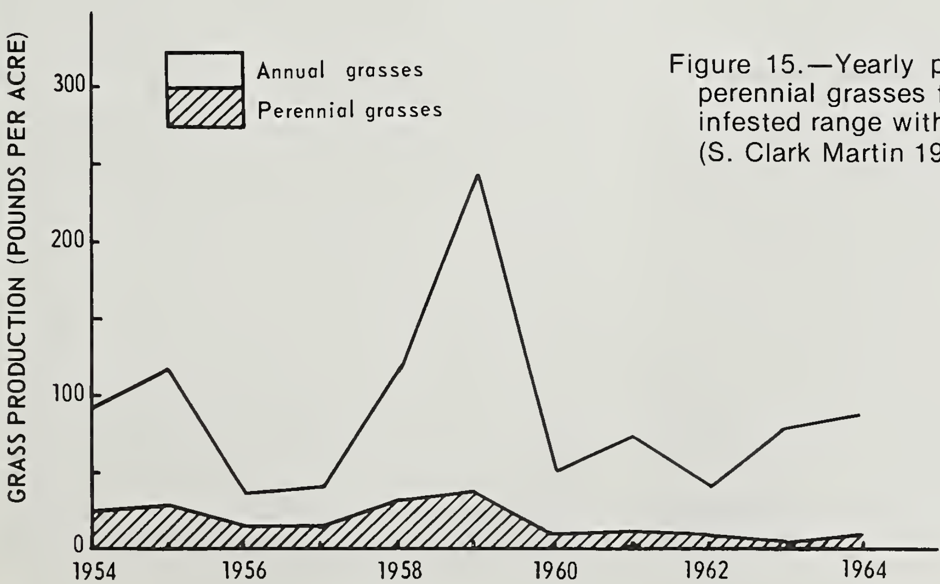


Figure 15.—Yearly production of annual and perennial grasses for a 5,000-acre mesquite-infested range with 12 inches annual rainfall (S. Clark Martin 1966).

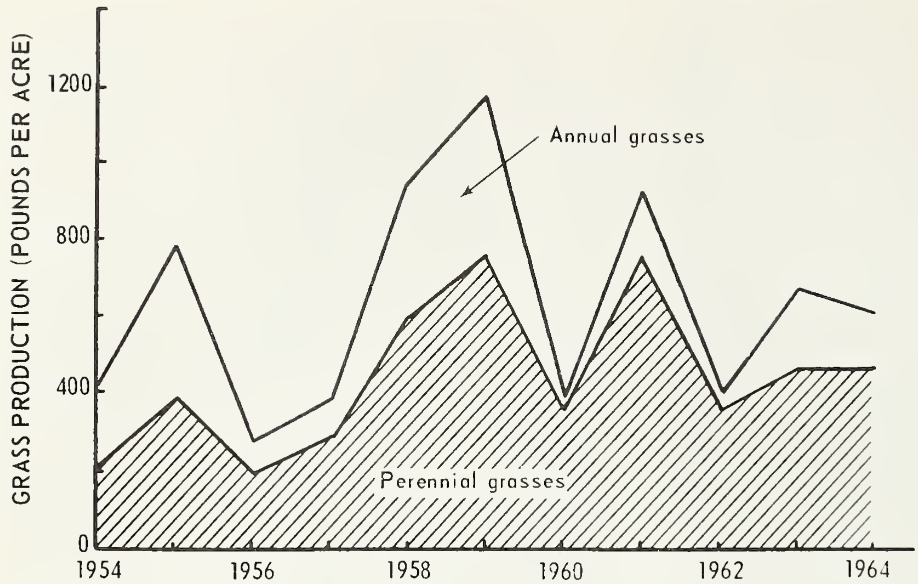


Figure 16.—Yearly production of annual and perennial grasses under a scattered stand of mesquite with 16 inches average annual rainfall (S. Clark Martin 1966).

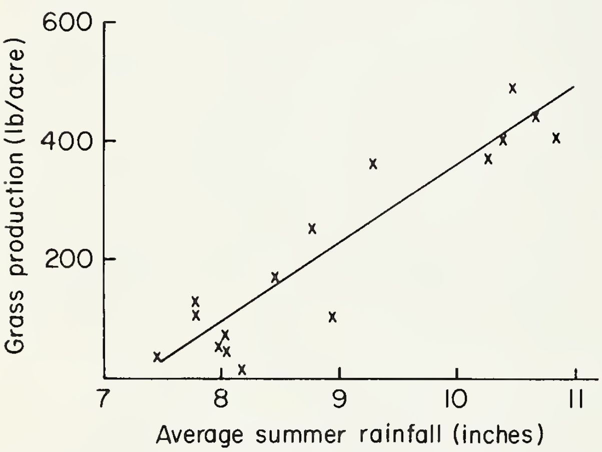


Figure 17.—Relation between average June-September rainfall (inches) and average perennial grass production per acre (pounds) from 1954 through 1968 for 16 pastures on the Santa Rita Experimental Range.

Range Condition, Grazing, and Drought

Ranges in excellent condition support a good mixture of the taller perennial grasses such as Arizona cottontop and sideoats grama. Plants are vigorous and provide a good cover of living and dead material. Low-growing species such as curly mesquite and sprucetop grama, short-lived perennials such as Rothrock grama, and annual grasses are minor forage components.

On the ranges in poor condition, the taller perennial grasses are limited to beneath the crowns of shrubs, or to exceptionally favorable or inaccessible sites. Even the low-growing perennials are not producing in the open. Herbage is composed mainly of annuals and short-lived perennials. Woody plants may form the dominant aspect and the soil is poorly covered with living or dead material.

Droughts, particularly of three or more consecutive years, can change species composition, vegetation cover, and herbage production, and can reduce range condition seriously despite past or present grazing management. Recovery of ranges from drought, however, is much more rapid on ranges that are moderately grazed than on those that have been overgrazed (Paulsen and Ares 1962). In fact, moderately grazed ranges recover even faster than ranges under complete protection. Thus, grazing can be beneficial to perennial grass stands. But the beneficial effects of grazing have received little research attention.

Site Potential

The incentive to improve semidesert ranges is limited by their inherently low productivity. Too often, however, the potential productivity of such ranges is not known and probably is underestimated. The problem is especially acute because examples of ranges that are producing maximum or near-maximum yields of forage for the site often are not

available. To underestimate the productivity of the range is to discount the value of returns to be gained by improvement. Thus, potential productivity, like carrying capacity, is basic to management. The development of site potential standards is a high priority job. Such standards will give the public land administrator and the rancher realistic guides as to how well they are doing and how far they have yet to go.

First priority for research on production potential is to develop readily comprehensible standards of productivity for major semidesert ecosystems. For bunchgrass ranges the measure could be number, and species, of perennial grass plants per unit area. One desirable perennial grass plant per square foot, for example, might constitute a full stand for a given combination of soil precipitation, elevation, slope, and exposure. If the existing stand on such a site is only 1 plant per 10 square feet, or if the species present are poor in quality, the opportunity for improvement is evident.

Seeding

Some ranges are so seriously deteriorated that native grass will not recover in a reasonable time. Also, there are localized stock concentration areas on nearly all ranges where the native grass stand has been depleted. Seeding to exotic species sometimes can provide more and better quality forage in the early spring. Thus seeding can simply provide more forage, or it can provide forage of higher quality at a critical time of year.

Reliable seeding methods are known for the better sites on grass-shrub ranges (Anderson et al. 1953). Fairly level sites with deep, fertile, medium-textured soils are best for seeding. Herbel et al. (1973) reported good success seeding ranges receiving 9 inches of rainfall in New Mexico. In Arizona, seeding is not generally recommended where annual rainfall is less than 11 inches. If stands of mesquite, cactus, or burroweed are moderate to dense they should be controlled before seeding. Grazing of seeded areas should be closely controlled until the stand is well established.

The best species for seeding vary with the site. Above 4,000 feet and 14 inches of annual rainfall, Lehmann and Boer lovegrasses have been the most consistently successful. Blue grama, Arizona cottontop, and black grama are also good species, but are difficult to establish. There are no commercial seed sources for the last two species. On upland sites in Arizona, where annual rainfall averages less than 13 inches, only Lehmann lovegrass has been established consistently. On bottomland sites or soils where moisture accumulates, blue panicum, Johnsongrass, Lehmann lovegrass, and Boer lovegrass grow well.

Good seedbed preparation is essential for success. The main purposes of seedbed preparation are to remove competing vegetation, cover seed, and promote moisture penetration. The eccentric disk and the intermediate pitter meet the objectives. Contour furrowing and ripping have also given good results. The recommended soil covering for seed is 1/8 inch for small-seeded species such as Lehmann lovegrass, and 1 inch for large-seeded species. A cultipacker seeder has proved best for covering small seeds. Larger seeds are best planted with a drill.

May and June just prior to the summer rains are the best months for planting. New stands should not be grazed until the second grazing season, or until seed has been produced. Once seeded grasses are established, the proper degree and season of use should be observed. Natural concentration areas for cattle cannot be successfully seeded to highly palatable species under continuous grazing. Rodent and insect control are sometimes necessary also.

Seeding where annual precipitation is less than 12 or 13 inches is risky, but the chances for success can be greatly enhanced by seeding in pits or by other soil treatments that increase infiltration or surface water. In a variety of tests, intermediate pits (basins approximately 5 feet square) have been more successful than conventional cut-away disk pits for establishing and maintaining stands of such species as Lehmann lovegrass and buffelgrass (Slayback and Cable 1970, Slayback and Renney 1972). Some means of collecting or concentrating water is especially important where annual rainfall is 10 inches or less.

Distribution of pelleted seed by airplane has been tested extensively with negative results. Clay pellets containing seed do not penetrate the soil on dry, unplowed range. The clay pellets dissolve quickly in the rain, leaving the seed perched somewhat above the soil surface on what remains of the melted pellet. If fertilizer is included in the pellet, it may decrease germination or it may cause the roots of the germinating seedling to concentrate near the surface and be especially susceptible to drought. The present state of the art is such that pellet seeding by airplane simply does not work (Hull et al. 1963, Jordan 1967, Chadwick et al. 1969).

At present, the expense and low probability of success is such that range seeding should be limited to sites where: (1) prospects for success are most promising, (2) the remnant stand of perennial grasses is so depleted that natural recovery with improved grazing management would be extremely slow, (3) competing vegetation is not excessive, and (4) grazing can be controlled. Adapted species, and approved methods of ground preparation and seeding should be used. Pitting, mulching, shrub removal, and rodent control should be employed if needed. Generally speaking, ranges should be seeded

only if they will not respond fairly quickly to improved grazing management.

Seeding research should continue, but ranks lower in priority than grazing management. The rationale is that grass stands usually cannot be established by seeding where the native perennial grasses were driven out by the prevailing system of grazing.

Additional research is needed to develop and test pitting equipment that will enhance the chances of success where annual rainfall is less than 12 inches.

Plant Control

Good grazing management helps maintain vigorous stands of perennial forage grasses. Although a dense grass cover reduces the rate of increase of aggressive shrubs, even the best management will not keep these shrubs from eventually taking over many sites. On such ranges, persistent effort is required to prevent the development of moderate to dense stands of undesirable shrubs.

Mesquite

Mesquite invasion is considered detrimental throughout the semidesert range area. The first objection to mesquite is that it reduces the density and herbage yield of grasses (fig. 18). Mesquite foliage is used by livestock to some degree, and the flowers and fruits are high-quality forage, but forage production by mesquite does not compensate for the decline in grass production as mesquite becomes thicker. McGinnies and Arnold (1939) found that mesquite requires three to four times as much water to produce a unit of dry matter as do native perennial grasses. Even moderate stands (as few as 25 trees per acre in Arizona, for example) may cut herbage production in half. By reducing grass density, mesquite also induces or accelerates sheet and gully erosion. The lateral roots of mesquite remove moisture from the soil between the trees as well as beneath them. Wind tends to sweep litter and topsoil from the relatively bare areas between the trees and deposit it under the mesquite crowns. The net result is that growing conditions between trees become increasingly difficult and erosion accelerates.

Mesquite is also objectionable because it increases the cost and difficulty of handling range cattle. As the cost of range labor increases, this factor becomes increasingly important.

Several factors have contributed to mesquite increases on semidesert range. Range livestock have contributed both directly and indirectly. By consuming mesquite beans, many of which pass through the digestive tract of a cow, cattle have spread mesquite seeds throughout the grazed area. This is only one reason why mesquite stands usually are heaviest where cattle naturally congregate. Cattle have contributed indirectly to the spread of mesquite by overgrazing and weakening the stands of perennial grasses. Vigorous perennial grasses compete strongly with mesquite seedlings. Experiments on the Santa Rita Experimental Range show that 16 times as many mesquite seedlings were established on bare areas as in vigorous stands of perennial grasses (Glendening and Paulsen 1955). Grazing also may have contributed to the spread of mesquite by reducing the amount of fuel for and the incidence of range fires.

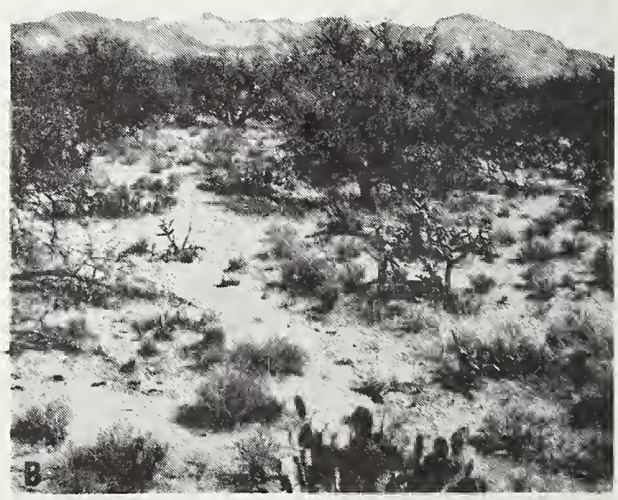


Figure 18.—Grass cover declines as mesquite increases:

A, view of native grass haying operations in 1903;

B, same site in 1964.

Mesquite-infested ranges can be restored to full productivity only if the mesquite is removed. Grass response following removal of moderate to dense stands of mesquite is excellent on sites with more than 8 inches summer rainfall and a good perennial grass remnant (fig. 19). A variety of mesquite control methods have been developed. No method so far developed is completely satisfactory, and each is peculiarly adapted to rather specific situations. Available methods include: (1) hand grubbing of mesquite seedlings, (2) individual tree treatment with diesel oil or with diesel oil containing herbicides, (3) application of granular herbicides to the soil around trees, (4) aerial spraying with herbicides, (5) individual tree dozing, (6) cabling or chaining, (7) roller chopping, (8) root plowing, and (9) prescribed burning.

Hand grubbing, which is effective for plants up to 1 inch in diameter at the groundline, is best for early invasion stands or colonies of small mesquites on relatively rock-free soils. In Arizona, the best time for grubbing is in the late spring when mesquite plants are green and easy to see in the dormant dry grasses. Grubbing is a labor-intensive method. It will not pay immediate returns on the investment because the removal of small seedlings does not increase forage production perceptably. Economically, grubbing must be justified as preventive maintenance—insurance against future production decline.

Diesel oil, like grubbing, requires so much labor that it is suitable mainly for small areas where mesquite control is especially needed. The method consists of spraying diesel oil against the trunk of the tree at groundline. Oil must saturate the bark on all sides of the stem and in the crotches. A gallon of diesel oil will treat four to eight trees. Mesquites that branch at or above groundline and have no more than five stems can be killed. Diesel oil fortified with 2,4,5-T is somewhat more effective than straight diesel oil, but the added cost is not usually justified. Diesel oil is not suitable for "dune" or "running" mesquite, nor is it suitable for use on flood plains where the bud zone has been buried beneath several inches of silt. Oil can be applied any time of year with kills up to about 90 percent, but cool-season treatments give slightly higher kills, and labor is somewhat more efficient when the weather is not too hot. Diesel oil, if properly applied, will kill either trees or stumps.

Immediate and often dramatic increases in forage production are obtained by killing moderate to dense stands of mesquites if there is a remnant of perennial grass.

Individual mesquites can also be killed by applying granular herbicides to the soil around the base of the trees. Monuron, fenuron, and karbutilate are effective when properly used. The advantage these herbicides have over diesel oil is that they are effective against any growth form of mesquite. One disadvantage of these materials, and others still under test, is that they kill a larger spot of grass at each tree than is killed by the diesel oil method. Other disadvantages include: (1) their relatively high cost, (2) unresolved questions about their total impact on the environment, and (3) legal restrictions (karbutilate, for example, has not yet been registered for use on rangelands).

For extensive control, application of herbicides by air is promising. Low-volatile esters of 2,4,5-T, when applied 2 years in succession and at the right time,

A

B

Figure 19.—Recovery of perennial grasses following mesquite removal: **A**, sparse growth of grasses in undisturbed stand of mesquite; **B**, adjacent mesquite-free plot produced an abundant forage crop composed mainly of Arizona cottontop and other native grasses.

provide effective control. Addition of picloram or other substances to 2,4,5-T has enhanced the kill in some experiments, but results have not been consistent.

Aerial applications of 2,4,5-T rarely kill more than 50 or 60 percent of the trees outright, but effective applications usually kill 90 percent or more of the top wood and markedly increase perennial grass production. Regrowth of mesquite after aerial spraying is relatively slow. On the Santa Rita Experimental Range, for example, mesquite control in 1954 and 1955 was still providing increased forage production in 1974. Greater increases in forage production could still be obtained by spraying a new area than by respraying the tract that was first sprayed 20 years before.

Aerial spraying leaves the top wood standing. Although the standing dead trees are esthetically displeasing, reduce visibility, and add to the difficulty of working cattle, they may provide some wildlife benefits.

Because the critical time for spraying mesquite with 2,4,5-T usually does not coincide with periods of active growth for other plants, the damage to species other than mesquite usually is negligible. Grasses are not visibly damaged, nor is there evidence to indicate that 2,4,5-T has been seriously detrimental directly to animals. The major impact on small animal populations probably results from changes in vegetation. Animals that do best in relatively sparse stands of grasses mixed with shrubs undoubtedly are affected adversely. Grassland species, on the other hand, should benefit. Since spraying does not result in 100 percent kill, sprouts from treated trees provide adequate mesquite foliage for browsing animals. On the other hand, spraying does stop production of flowers and fruits for several years. Until the impact of 2,4,5-T and related herbicides on the environment has been more completely assessed, these materials should be used only if the proposed use is approved by the appropriate pesticide control authorities.

Individual tree dozing is a good method for removing scattered stands of mesquite. It is effective on all growth forms and at any time of year, except that small seedlings are likely to be overlooked. When carefully done, bulldozing kills a high percentage of the mesquite and has the advantage that the stumps are removed and the trees are knocked down. With little extra expense, the uprooted trees can sometimes be pushed into arroyos, leaving the bulk of the area free of obstructions. Increases in herbage production following bulldozing depend largely on the degree of release obtained and on the ability of the remnant grass to respond. Bulldozing is more acceptable than chemical control in some areas because it does not introduce herbicides into the environment.

Two tractors dragging a cable or anchor chain between them can be used to knock down either dead or live mesquite trees of almost any size. Cabling in both directions will uproot most trees that have stems stiff enough to flip out the root systems. The cable or chain will simply slide over smaller trees (up to about 2 inches in diameter) and thorny shrubs such as catclaw acacia and wait-a-bit without damaging them seriously. Areas with moderate to heavy densities of these thorny shrubs probably should not be chained, as they tend to increase and become more vigorous after the mesquite overstory is removed. Thus a major disadvantage of cabling or chaining is that it usually results in rapid regrowth of sprouts from smaller trees.

Cabling knocks down not only the mesquite but other kinds of brush as well, and thereby provides an uninterrupted view. This has a real advantage from the standpoint of handling livestock. The major disadvantage, as previously indicated, is the low percentage kill, particularly on younger trees and shrubby understory species. Cabling must always be followed by other control measures. Spraying individual sprouts with herbicides, aerial application of herbicides, and burning are possible maintenance measures.

In dense stands of mature tree-like mesquite, the percentage kill by cabling may be about the same as with aerial spraying with 2,4,5-T. Spraying usually costs less than cabling, but it does not immediately provide a brush-free aspect. Followup is required in either case, but when all things are considered, cabling often is the better choice for cattle ranges infested with tree forms of mesquite.

Cabling is not effective on the low-growing, many-stemmed growth form of mesquite. On sandy soils where the many-stemmed mesquite forms dunes, cabling disturbs the soil too much and leads to excessive wind erosion. For mature dune-type mesquites, aerial spraying is preferable to mechanical control.

Huge roller choppers completely smash down all woody vegetation and provide a clear view, as does cabling or chaining. In fact, chopping may provide an even more uncluttered view because it does not leave the brush in piles as chaining or cabling sometimes does. Percent mesquite kill by chopping probably is no greater than with cabling, so followup measures are needed to maintain a brush-free aspect. Chopping and cabling do not destroy remnant stands of perennial grasses, although some plants are killed.

Although root plowing is the most destructive mechanical method of removing mesquite, it is also the most effective, because it uproots all plants in the area. Plants that survive are mainly those at the edge of a swath that are not completely severed by the blade. Small plants that are cut off but not flipped out also may survive, especially if the soil

becomes wet soon after plowing. Root plowing destroys or seriously disturbs all vegetation including the perennial grasses. Therefore, seeding at the time of plowing is usually essential for the prompt reestablishment of a forage stand. However, Mathis et al. (1971) reported that herbage production 5 years after root plowing was lower on seeded range than on range that was not seeded.

Prescribed burning can rarely be used to control moderate to dense mesquite stands because such stands seldom produce enough fuel to carry a fire. A hot fire in June may topkill almost all small mesquites (up to ½ inch in stem diameter at groundlines) and kill about 50 percent of them outright (Glendening and Paulsen 1955), but very few trees larger than 4 inches in basal stem diameter are killed. The only place for prescribed burning in mature mesquite stands, therefore, is following some other method that has seriously weakened or killed the original trees. Once the original stand has been controlled by mechanical or chemical methods and a stand of grasses has become reestablished, periodic burning may be useful for controlling reinvasion and regrowth. Burning at suitable intervals will kill small plants back to the groundline periodically, and keep most of them from maturing and producing seed.

Ecologically, burning is not necessarily cheap. Fires that will kill mesquite will also kill grasses. Burning studies on the Santa Rita Experimental Range show that Santa Rita threeawn is not seriously damaged by fire, but that tall threeawns are. The difference apparently results because Santa Rita threeawn is randomly disturbed, mostly in the openings between shrubs, whereas tall threeawns grow mainly in shrub crowns where they are subjected to greater heat as the shrubs burn. Also, Santa Rita threeawn remains green at the base while tall threeawns dry to the groundline, thereby providing fuel for their own destruction. Unfortunately, many of our better long-lived grasses are severely damaged by fire and are very slow to recover. A June fire, for example, killed 90 percent of the black grama, compared to less than 50 percent of the mesquite (Cable 1965). In this case, fire killed almost all of the Lehmann lovegrass plants, but a new stand became established from seed during the summer immediately following the burn. Obviously, burning favors species that can survive a fire or quickly reproduce themselves from seed. Our best forage species are deficient in these attributes. A fire that kills 90 percent of the grass but only from 10 to 50 percent of the mesquite may not be desirable.

Creosotebush

Creosotebush occupies vast areas of the more arid semidesert region. Gardner (1951) reported that creosotebush has occupied much former grassland in New Mexico since 1850. Its grazing value is nil, and herbage production in moderate to dense stands of creosotebush is negligible. Some ecologists believe that creosotebush even has the ability to replace mesquite on areas that formerly were grassland.[6] Since creosotebush occupies ranges with relatively low potential, the response of perennial grasses to removal of creosotebush often is not striking. Grass stands where creosotebush predominates usually are so sparse that the cost of high-risk seeding must be added to those of shrub control. Therefore, even though responses may sometimes be dramatic, control of creosotebush is not often economically feasible.

Because of the economics involved, less work has been done on control methods for creosotebush than for mesquite. Creosotebush is relatively resistant to aerial applications of most herbicides. It is a vigorous crown sprouter and its stems are too flexible for effective chaining or cabling. Modified chains such as the Dixie sager may have possibilities. Root plowing is effective, but is often too expensive to be justified. Abernathy and Herbel (1973) report that shrub control, basin pitting, and seeding with a machine that does all three jobs at one pass will pay on selected creosotebush sites in southern New Mexico. A positive feature is that fourwing saltbush is often found growing intermingled with creosotebush. On such areas, removal of the creosotebush sometimes results in a good stand of fourwing saltbush, a much more valuable shrub, after a few years.

Recent work at the University of Arizona indicates that creosotebush (particularly young plants) is susceptible to fire (White 1968). Fire cannot be used in dense mature stands of creosotebush, however, because they rarely if ever provide enough herbaceous fuel to carry a fire. One possibility is to use fire following other treatments. Once the creosotebush has been removed and a stand of herbaceous vegetation established, fire might be used to prevent reinvasion. The prospects are only moderately good at best, however, because rainfall where creosotebush thrives does not often produce enough herbage to carry a fire.

Cactus

Various cacti species are a nuisance on substantial areas of semidesert range. Most widespread in southern Arizona are the cholla or tree cactus forms that predominate at the lower elevations and lower rainfall portions of the region. Cholla is a problem

[6]*Notes from "Impact of grazing on the ecology of the Southwest," by Dr. W. A. Dick-Peddie, at 21st Annu. Meet., Am. Soc. Range Manage., Albuquerque, N.M., Feb. 1968.*

primarily because it occupies space and interferes with handling of cattle. It does not appear to compete seriously with perennial grasses. Due to the spines, however, grasses that grow under cholla are not available to cattle. Thus cacti interfere more with the use of grasses than with their growth. Cholla stands in southern Arizona usually are not permanent (fig. 20). Stands tend to increase over a period of years, then die from natural causes. The cycle from invasion to die-off may run 40 to 50 years.

Figure 20.—Changes in jumping cholla:
A, in 1905 cholla was just beginning to invade;
B, by 1941 a dense mature stand had developed and had started to decline;
C, very few live cholla remained in 1962.

The chollas are fairly resistant to light applications of such herbicides as 2-4-5,T and 2-4,D. Each plant must be completely wetted. Chollas can easily be knocked down with a cable or chain. This method is quite effective in senescent stands. The number of rooted chollas per acre may jump manyfold after cabling due to the rooting of joints on the ground, but most of these new plants die in about 3 years (Martin and Tschirley 1969).

Fires in June have killed about 50 percent of the cholla on the Santa Rita. Surviving plants usually were large individuals that were only partially burned. Periodic burning should be an effective tool for preventing cholla invasion.

Pricklypear is a problem mainly where rainfall is somewhat higher than on areas occupied by cholla. Pricklypear apparently is less conspicuously cyclic than the cholla. It is equally hard to control with herbicides and about equally susceptible to fire.

Burroweed

Burroweed is of concern primarily in southern Arizona and southwestern New Mexico. Although it is toxic, native cattle are rarely poisoned. It germinates in the fall or winter on cool-season moisture. It competes less severely with the grasses than does mesquite because (1) it grows primarily in the spring whereas grasses grow mainly in the summer, and (2) because its taproot system draws less heavily from soil moisture near the surface than is the case for perennial grasses. Burroweed stands tend to build up if cool-season moisture is above average, and decline when cool-season moisture is severely below average.

Grubbing, mechanical treatments, and prescribed fire can all be used to control burroweed (Tschirley and Martin 1961). Grubbing generally is too expensive. Mowing in June or July is effective, but only on relatively level, rock-free terrain. Results with herbicides such as 2-4,D have been erratic. Burning in June with 500 pounds or more of herbage per acre may kill up to 90 percent of the burroweed. Burning simply to control burroweed may not be feasible, however, not only because burroweed control does not greatly increase production of perennial grasses, but because many of the better perennial grasses are severely damaged by fires of the intensity needed to kill burroweed. Also, burroweed can quickly reoccupy the burned area if cool-season precipitation is high.

The fact that burroweed stands usually decline of their own accord after a few years also reduces urgency for burroweed control. Wooton (1916) reported an invasion of burroweed in 1903 near the southwest corner of the Santa Rita Experimental Range. By 1917 a considerable part of the burroweed was dead. Wooton attributed death of burroweed to crowding by grass. Whatever the cause, burroweed stands apparently were changing from year to year during the first two decades after the range was established. Two additional burroweed invasions have been recorded since. One reached its zenith around 1935, the other in 1968.

Another reason for caution about burroweed control is that most of the perennial grass plants on a rundown range are intermingled with burroweed or other shrubs. Removing the burroweed from such ranges would expose these remnant perennial grasses to increased grazing. Therefore, burroweed control on ranges where grazing is excessive may only accelerate the decline of perennial grasses.

Snakeweed

Snakeweed, also a cool-season germinator, is more widespread than burroweed. Like burroweed, it is toxic although usually not fatal to cattle. More commonly, consumption of snakeweed by cattle results in abortion. Snakeweed can be controlled with ester formulations of 2-4,D. Aerial or ground sprays of 1 to 1½ pounds per acre (acid equivalent) in 10 gallons of water or oil-water emulsion are recommended. Spraying 2 years in succession is often necessary to control seedlings that emerge after the initial spraying. Time of spraying is critical. It should be done early in the spring when new growth is 3 to 5 inches and while there is enough moisture in the soil to keep plants growing 2 or 3 more weeks.

Snakeweed differs from burroweed in that it has a fibrous root system that occupies about the same soil levels as the roots of perennial grasses. Thus snakeweed may compete more directly with grasses than burroweed does.

Summary

The current situation with respect to shrub control is that, except for mesquite, control of noxious shrubs on semidesert range is not universally desirable. Some species such as burroweed and snakeweed increase and decrease in response to precipitation, and compete only moderately with perennial grasses. Cholla too competes only moderately with perennial grasses, but is objectionable because it interferes with the handling of cattle. Creosotebush competes seriously with herbaceous plants, and like mesquite seems to move in permanently, but economical methods for converting creosotebush stands to grass have not been developed.

Mesquites are the most consistently objectionable invaders of semidesert range. Mesquite control is recommended wherever perennial grass production is a major objective and benefits justify the cost.

Benefits may be in terms of increased forage production, or as insurance against a future decline in production as the density of mesquite increases and trees grow larger. Several control methods are available. The method used should be suitable for the kind of mesquite, for the site, and for the short- and long-range ranch management objectives. If beef is the only salable ranch product, complete clearing may be a reasonable objective. On the other hand, if opportunities to develop income from hunting privileges or other recreational enterprises are good, it may be desirable and profitable to leave patches of mesquite for wildlife food and cover.

More effective and more economical mesquite control methods are urgently needed. With current concern about side effects of herbicides, as well as about the desirability of tampering with range vegetation at all, more comprehensive ecological approaches are in order. The impacts of herbicides must be determined for nontarget species, and the impacts of resulting vegetation changes on bird and mammal populations should be a matter of record. Research on direct control methods should include combinations of treatments such as aerial spraying or cabling followed by burning or individual tree spraying, or cabling followed by aerial spraying.

Research on control methods for shrubs other than mesquite is of moderate priority—less important than grazing management.

Prescribed burning cannot be generally recommended on the basis of current knowledge. Fires that kill shrubs usually kill grasses too, and fires that spare the grasses may also spare the shrubs. Burning usually favors annual grasses and pioneer perennials at the expense of the better, longer-lived perennials. Still, periodic burning, combined with improved grazing systems, may effectively control semidesert shrubs. Research to learn how fire may be used acceptably and to good advantage should have high priority.

Emphasis in fire research should be on: (1) determining the responses of major grasses and shrubs to periodic burning, (2) fitting prescribed burning into schedules of grazing and rest, and (3) defining acceptable conditions for controlled burning.

Rodent and Rabbit Control

Rodents and rabbits use vegetation that would otherwise be available for livestock. Rodents and rabbits can be more detrimental to range plants than cattle because they graze much closer and may even dig up the plants during dry periods. Because populations of jack rabbits and kangaroo rats tend to be highest on ranges in poor condition, their impact becomes more severe as productivity declines. Certain species (the Merriam kangaroo rat, for example) help establish shrubs by burying seeds in shallow surface caches at the optimum depth for germination.

Direct methods of controlling rabbits and rodents by poisoning, trapping, shooting, rabbit drives, etc. usually provide only temporary relief and are rarely worth the cost. Prairie dogs have been eliminated from most of original range, it is true, but most other small mammals have survived man's most determined efforts to exterminate them. Vegetation management appears to offer a better approach to animal control. Improving the condition of a range from poor to good often eliminates the most evident rodent problems, but rodent control may be needed initially to start the upward trend. The availability of preferred food and cover as well as the balance between prey and predator species may be affected by the amount and kind of vegetation. And, while the causes and effects are not always clear, ranges in good to excellent condition rarely have serious rodent problems.

Fertilizer Applications

Fertilizers have been applied to rangelands to increase forage production, to lengthen the green forage period, to improve the chances for successful establishment of seedlings, and have been suggested as a means of attracting cattle to little-used parts of the range. Fertilizers sometimes increase herbage production greatly, especially in seasons of above-average rainfall. These increases, though dramatic, may be of little practical use because ranges that are properly stocked always produce a surplus of forage in years of high rainfall. The extra forage produced by applying fertilizer in a wet year has little value for the rancher if he does not have enough animals to use it. Fertilizer applications would be much more helpful if they could be used to increase production in years of forage scarcity.

Fertilizers may have a place in the improvement of livestock distribution and in utilizing relatively unpalatable species. Applications of fertilizer often result in closer utilization of the fertilized plots. In many cases the fertilized plots are grazed evenly with no apparent selectivity among species. This suggests that fertilizers can be used to enhance the palatability of forage in areas that cattle often pass up. The economics of such applications have not been investigated.

Fertilizer may raise average levels of forage and livestock production above those that can be reached simply by improved grazing management, seeding, and shrub control. In the northern plains, for example, Rogler and Lorenz (1957) found that applying 90 pounds of nitrogen per acre for 2 years improved range condition more than did 6 years of rest.

In the Southwest, common observation indicates that plants growing under mesquite trees where soil fertility is higher withstand repeated grazing much better than grasses growing between shrubs on impoverished portions of the soil. These observations suggest that appropriate fertilizer applications may help perennial grasses survive and recover from drought. Much additional research is needed to establish appropriate levels of fertilization and to determine relative cost-benefit ratios.

Present knowledge is too limited to support general recommendations for range fertilization. Research has been limited mainly to empirical tests of the effects of fertilizers on herbage production immediately following application. A comprehensive program of basic research is needed. Areas that deserve immediate attention include: (1) effects of moderate to light applications of nitrogen or other nutrients on the species composition of the herbaceous vegetation, (2) effects of light to moderate fertilizer applications on herbage yield during moderate to severe drought, (3) effects of fertilizers on ability of grasses to withstand drought, (4) effects of fertilizers on ability of grasses to compete with seedlings of mesquite and other shrubs, (5) possibility of increasing herbage production in years of average or above-average rainfall to the point that native hay may be harvested for use in drought, (6) possibility of using fertilizers to raise the average level of production above the maximum attainable by management alone, and (7) possibility of using fertilizers to extend the green forage period.

Water Spreading

Opportunities to divert flood water from drainages to adjacent land exist on many ranges. On the average ranch such efforts should be confined to relatively small watercourses where water can be diverted without excessive expense, and where the risk of doing more harm than good is not great.

In a review of water spreading reports, Miller et al. (1969) concluded that water spreading did not do much good on thin or shallow soils. They found that yields greater than 1,000 pounds were obtained from soils capable of retaining between 14 and 40 centimeters of water, and recommended that flood-water spreaders should be restricted to soil deep enough to store at least 12 centimeters (4.7 inches) of water.

Increasing Usability of the Range

Water Development

Permanent natural waters on semidesert range are so few and so widely scattered that only a very small percentage of the area could be properly grazed by livestock from these natural waters alone. During the early days of livestock production on these ranges, vast areas could be grazed only intermittently. At times, lack of water saved these ranges from severe overgrazing, because livestock died or were removed during drought.

Ranchers and range investigators alike gave early attention to the development of livestock water. Barnes (1914) described the need for water on the range, methods for developing natural watering places, and possibilities for developing artificial watering places. The general principles of range water development are well established (Talbot 1926, Hamilton and Jepson 1940).

Talbot (1926) stated that permanent waters should not be farther apart than from 4 to 5 miles in flat or undulating country (14 to 24 sections per watering place); 3 miles in rolling country (6 to 12 sections per watering place); and from 1 to 2 miles on rough ranges (from 1 to 4 sections per watering place). Water development on most ranges in the Southwest probably meets these minimum standards of spacing and frequency. Many ranges of moderate to high productivity have more water places, while some of those of very low carrying capacity do not yet meet Talbot's standards because of the cost.

More recent writings deal largely with refinements of the basic techniques, and include such developments as deep-pit charcos, sand tanks, temporary ponds, and methods of reducing losses due to seepage and evaporation. Additional developments include (1) paved runoff areas with closed storage (trick tanks), and (2) horizontal wells (a method of developing weak springs or seeps).

Water development of any kind is expensive. Culley (1938b) stated that careful planning is required to insure that water is placed where it will yield the greatest return. He cited an example in which, by careful placement, a particular water source was made to serve 350 head of cattle rather than 120, and the investment per cow thereby reduced from $13 to $5. The cost of water development, when added to other investment costs, must not raise the investment load per cow above what can be economically justified.

Water development still is not adequate on many semidesert ranges. In some cases the water problem has been aggravated because springs or seeps now produce less water than they once did, or have ceased to flow altogether. Watersheds have become covered with shrubby vegetation that consumes so much water that none is left for underground flow, or, alteration of the soil surface through deterioration of the grass cover has reduced infiltration and percolation. In some areas it may be cheaper to restore the flow of streams or springs through shrub control than to drill wells to replace the original source.

Where underground water exists at reasonable depths, deep wells are the most reliable source of livestock water. Pumps powered by windmills with gasoline engines for standby power provide the permanent water on most ranches. Shallow wells are also common and useful, even though some of these do fail in periods of protracted drought. Storage tanks are necessary at most wells because either the well or the pump will not furnish more than a few gallons per minute. Where wells are very weak, covered storage is advisable to cut down evaporation.

Surface ponds are common on the semidesert ranges. Ponds range in size from very small developments which hold water for only a few weeks to large, deep structures that may hold water permanently. Ares (1936b) found that small inexpensive ponds enabled cattle to make better use of tobosa grass during the summer growing season, thereby reserving more of the black grama for the dormant season. These temporary ponds also decreased the grazing pressure near permanent waters. Hamilton and Jepson (1940) reported that ponds in the semidesert range area should be from 10 to 14 feet deep to provide reliable water yearlong. Most stock ponds are not nearly that deep, and provide water for perhaps half the year. Use of clay products or salts such as sodium carbonate to reduce seepage can reduce the necessary pond depth. If ponds are to be long lived, they must be properly constructed and placed so that they are not subject either to being washed out or filled with sediment during high flows. Areas above ponds should be fenced to allow vegetation to develop and trap sediment, thereby lengthening the useful life of the ponds. Water used by the vegetation in the silt trap is not enough to offset the value of the protection it gives.

Evaporation losses from ponds have always been a serious concern. In the Tucson area, for example, it has been estimated that a square foot of water will evaporate 50 gallons of water per year.

Three approaches to evaporation control are: (1) the use of hexadecanol, which has been only moderately successful because of the difficulty of maintaining a film of material on the water (Cooley 1975), (2) the use of styrofoam rafts floated on the water (Cluff 1972), and (3) a layer of wax for steel or concrete tanks (Cooley and Myers 1973). None of these are entirely satisfactory. Hexadecanol films are swept off by strong winds, styrofoam rafts break up eventually and must be replaced, and sufficient quantities of wax are not always easy to get.

A growing problem with ponds on some ranges is that, as management and the vegetation cover improve, once-reliable stock ponds rarely fill because the watershed has become more like a sponge than a tin roof. As the condition of the range improves, forage becomes more abundant but surface water less so. Faced with this situation, the rancher must make other arrangements for water; usually these involve tapping ground-water sources. Three developments within the last couple of decades offer some relief. These are: plastic pipe, trick tanks, and horizontal drilling.

If permanent water is available, plastic pipe can be used to distribute water from a central location at a relatively low cost. Flexible plastic pipe is not satisfactory in some areas, because gophers or other rodents gnaw through the pipe. In other areas the pipe must be carefully laid and covered to keep rocks from cutting the line. If flexible plastic pipe is not suitable, rigid plastic tubing is available at substantially lower cost than steel pipe.

Paved runoff areas with covered storage (trick tanks) also may be used to provide water for livestock. On some ranges the natural runoff from a paved road can be directed into storage; on others the runoff surface must be developed. A number of waterproof materials for covering the soil surface have been tried. These include butyl rubber, which is durable but quite expensive; polyethylene film, which is cheap but not very durable; concrete or asphalt, which are both quite durable but expensive; and treating the soil with salt or water-repellent chemicals. In all cases a relatively small collecting area is made quite impervious to water. The most expensive part of such projects usually is the development of enough storage to last through dry periods.

Horizontal well drilling is economical for special situations. Basically it is an improved method for developing seeps or weak springs in hilly or mountainous terrain. A horizontal hole about 2 inches in diameter is drilled into the side of the hill at the chosen site. A pipe perforated in the water-bearing area remains in the hole to collect and carry water to the surface. Since water flows out of the well by gravity, no pump is required. To avoid wasting water, however, it is advisable to limit the flow to actual use with a float valve directly on the well. Unrestricted flow might soon drain the well dry. Of 58 wells drilled on the San Carlos Indian Reservation in Arizona, only seven were reported to be failures in the fall of 1969. The average well was 97 feet deep (or long) and the average cost per producing well was $411.

The secret of successful horizontal well development is to drill in the right place. A competent geologist can improve the probability of success. However, the better horizontal well contractors are reasonably good amateur water geologists themselves.

Fencing

Range fences no longer serve only to keep the rancher's cattle at home; they also meet specific livestock and range management needs. Separate pastures for replacement heifers or for bulls during the nonbreeding season are common. For purebred herds, pastures are designed to carry the number of cows (usually 50 or fewer) that can be serviced by one bull. Or, the size of the pasture may be limited by the amount of stock water. Aside from such limitations as these, the number of cattle in a pasture probably is not critical, although calf crops reportedly are higher in units of about 50 cows than in larger units.

A major objective of crossfencing for subdividing a range unit is to provide opportunities for range improvement by such methods as seeding, shrub control, and systems of alternate grazing and rest.

Economics dictates that ranges be subdivided no more than necessary for good range and animal management. Conventional fencing with four barbed wires and steel posts about 30 feet apart may cost around $1,500 per mile on level soft ground; much more on rough, rocky, or bushy terrain. "Suspension" fences constructed of 13½-gage high-tensile-strength wire with posts 100 feet apart and stays between are less expensive than standard fences, and may well be effective so long as there is no great temptation for cattle to cross from one side to the other. Cattle with a strong inclination to cross the fence can learn to lift the wire midway between posts, however, and crawl under.

New fences should be located only after careful consideration of such factors as topography, vegetation type, natural trails, and water that affect cattle movements and access to all parts of the resulting range units.

Salting

Proper distribution of grazing is essential for efficient use of grass-shrub ranges. Salt or supplement can sometimes be used to draw cattle to areas where forage is abundant but not fully used.

For many years salt was placed at water on southwestern ranges in the belief that salt made cattle thirsty, and that placing salt away from water would cause cattle to go directly from salt to water. A number of observations, however, have shown that cattle ordinarily lick salt after drinking rather than before, and that when salt is placed away from water cattle usually leave the salt station to graze rather than go directly to water (Ares 1936a, Culley 1938a, Zemo and Klemmedson 1970).

Salt placed away from water, where forage is abundant, usually improves the distribution of grazing. If there is little or no salt in the vegetation and no natural salt licks, salt can be a relatively satisfactory distribution tool.

If cattle do not seek out a salt block that is placed away from water, or return to it once they know where it is, some other means of improving distribution will have to be used. This may happen on ranges with natural salt licks or with salt in the forage, as in saltbush stands.

Ares (1953) found that feeding meal-salt mixtures away from water greatly improved the distribution of grazing use by steers from November through June in southern New Mexico. Consumption of meal-salt declined when green herbage became available in the spring, a phenomenon confirmed in a more recent study in Arizona (Martin and Ward 1973). No evidence of salt toxicity was reported in either study. Ares also observed that cattle did not travel directly from the meal-salt station to water but continued to graze after feeding. These results show that meal-salt mixture can be used to improve the distribution of grazing use as well as to compensate for nutritional deficiencies in the native forage.

Riding

Riding to increase usability of the range may or may not do much good. The keys to successful riding are common sense, persistence, and culling. Pushing cattle to where the grass looks good but where there is no water is usually futile because the cattle will be found at their old location 24 hours later. The common sense rule, then, is to move cattle to grass only if there is water. Cattle may have to be met daily and pushed back to the new location for a week or more before they will accept the move. Animals that refuse to stay where they are put should be removed from the herd. Chronic cases of poor distribution may require additional water development, crossfencing, or a change in the grazing system, as well as persistent riding, to break up the old use pattern.

Trail Construction

Most semidesert ranges are relatively flat and easily traversed by cattle, but include some partial barriers to cattle movements. Trails built across steep-sided gullies or arroyos make it easier for cattle to get to where the forage is. Exit trails off roads that run across the slope on steep terrain may also be worthwhile. Some ranchers also report good results from crude trails on steep hillsides. Such crude trails

can be built with one pass of a moldboard plow. Trails should be so located and engineered that they do not develop into gullies.

Summary

Practices for increasing the usability of ranges grazed yearlong are almost standard and generally accepted. However, the usual recommendations for number and spacing of waters, size of range units, placement of salt, and the need for riding or for trail construction may have to be revised as ranges are converted from yearlong grazing to systems that include alternate periods of grazing and rest.

Except for critical distribution problems, the priority for continued research in trail construction is relatively low.

Livestock Management

Most ranchers are better versed in animal husbandry than in the ecology and physiology of range plants. This is natural because their income is derived from the sale of the animals rather than from the sale of unconverted forage. Acceptable solutions to most of the critical problems of range livestock husbandry have been developed. Nevertheless, there is room for improvement.

Every effort should be made to keep cattle gentle. Cattle that see a rider only at roundup time tend to become wild. Frequent riding, gentle methods, and modern conveniences for handling livestock greatly reduce losses and injuries. Holding traps, corrals, squeeze and separating chutes, and branding tables greatly reduce labor. Gentle cattle are much easier and cheaper to handle than are wild cattle.

Animal Nutrition

The nutritive quality of most semidesert range forage plants is adequate during the active growing period, but the common perennial grasses are usually deficient in protein during midwinter. Phosphorus and vitamin A are also inadequate at times. However, cattle are able to select the most nutritious forage from that available. On ranges where there is a variety of shrubs as well as grasses, cattle usually select a diet adequate in protein in all but the coldest part of the year (Cable and Shumway 1966). On grass ranges, however, cattle diets may drop below minimum levels of protein and phosphorus shortly after the first hard freeze, and continue deficient until growth resumes in the spring (Stanley and Hodgson 1933). In some situations, supplemental vitamin A may be needed in midwinter. On grass ranges, therefore, range cows probably should receive essential supplements from early winter until spring growth begins. On grass-shrub ranges the feeding period may be shorter or in some cases may be eliminated altogether. Range cows can be allowed to lose some weight (up to about 100 pounds) during winter without damage to health or serious decline in productivity. Feeding enough supplement to maintain body weight of cows during the winter is wasteful.

Animal Breeding

Hereford cattle predominate in the semidesert region. However, the February 1975 issue of New Mexico Stockman contains feature articles and/or advertisements for Angus, Simmental, Limousin, Charolais, Chianina, Scotch Highland, Brangus, Santa Gertrudis, and Beefalo as well as for Herefords. Crossbreds such as Barzona, Brangus, and Santa Gertrudis are gaining popularity on some desert ranges because the animals are better able to stand the heat and can travel greater distances between feed and water than can the common English breeds. Crossbreds are also favored on some ranges because they produce bigger, heavier calves. To some extent, however, the advantage of larger calves is offset by the fact that some crossbred herds produce lower calf crops.

Herbel and Nelson (1966) report that Santa Gertrudis cows consume more of the coarse grasses than the Hereford, but that the Herefords eat more Russianthistle and yucca. They also report that the Herefords spend more time grazing, less time walking, and travel less distance than the Santa Gertrudis. Generally speaking, the differences were not great enough to justify recommending one breed above the other. There is no consensus as to which other breed or crossbred will eventually exceed the Hereford in popularity.

The rancher must meet market demands. Sometimes larger calves are an advantage. At other times the greater weight is a disadvantage because feeders want smaller animals. Generally speaking, the packers prefer a heavier carcass because the cost of processing depends more on the number of animals than on the weight handled, and because the larger framed animal reaches an acceptable weight carrying less waste fat. If the apparent trend toward heavier animals continues, the heavier cattle breeds will continue to replace Herefords.

Another concern where grazing systems result in changes in pasture and herd size is the impact of such changes on calf crops. The effects of larger herd sizes on calf crops under complex grazing systems are uncertain. Bull-cow ratios in common use on semidesert range have evolved mainly out of experience under yearlong grazing. These ratios may not be optimum for more complex grazing systems.

Herd Composition

Cow-calf operations have predominated on semidesert range in the past, but recent and prospective economic developments suggest that cow-yearling operations may be more profitable in the future. Since semidesert forage produces rapid animal weight gains only during the summer growing season, most semidesert ranches have been cow-calf operations for good reason. Calves are born in the early spring and sold in the late fall as weaner calves. This schedule fits in well with the timing of forage growth. Calves born in January, February, or late December are large enough to take the increased milk flow during the summer rainy season, and usually are about as heavy in the late fall as they would be 6 to 8 months later after wintering on the range. Yearlings held over for a full year mark time for 6 to 8 months (November through April or June) and make all of their gain for the year during the remaining 4 to 6 months. Special situations that are better suited to yearlings or steers than to cows and calves include rough or rocky range that is better used by lighter, more active animals, and remote or brushy ranges where losses of young calves to predators are excessive.

For cow-calf operations on ranges grazed yearlong, Paulsen and Ares (1962) suggest that the breeding herds should be kept well below the average capacity for the range, and that extra forage in good years should be utilized by carrying over extra yearlings. In years of low production, the normal complement of yearlings would be sold and only the breeding herd would be kept. A serious shortcoming of flexible stocking in cow-calf operations is that each year's forage crop is not known until the growing season is over. If extra animals are put on the range in the fall following a good summer forage crop, they should be sold in May or June before the new growing season starts. In most years this is not profitable because weaner calves gain little in weight or value during the dormant season. Also, the range will be overstocked during the growing season unless forage growth is above average.

In a more recent evaluation of flexible stocking on a yearlong cow-calf operation, Martin (1975) found that net sales were highest when the breeding herd was maximized, and that it did not pay to stock above the average carrying capacity following summers of high production. The breeding herd was maximized by breeding cows to calve first at age 2 and by keeping a minimum number of replacement heifers. The number of replacement heifers can be kept small if cows are normally culled for age at age 8. If this is done, a cow can be held over an extra year or so if a replacement heifer dies, does not turn out well, or fails to breed back. If forage production is low, stocking can be reduced to 91 animal units by selling the replacement heifers. More severe cuts must come from the breeding herd. A 100-animal-unit cow-calf herd would consist of 87 cows and 15 replacement weaner heifers (0.6 AU each) and 4 bulls.

Cow-yearling operations offer greater flexibility for reducing stocking after dry summers but fewer animals are marketed than with cow-calf operations. Assuming 90 percent calf crops, and no death loss, with cows calving first at age 2 and culled normally at age 8, a 100-animal-unit cow-yearling herd would consist of 63 cows, 3 bulls, 11 replacement heifers, and 46 carryover yearlings. If necessary, the 46 carryover yearlings can be sold as calves, thereby reducing stocking to 73 animal units without selling breeding cows or replacement heifers. However, selling carryover yearlings as calves increases income this year but reduces it a year later.

The question is, which is the more profitable, a cow-calf herd or a cow-yearling herd? Much depends on the price per pound for calves and yearlings and on their average weights. Cattle prices through 1973 generally favored the cow-calf operator. Cattle feeders paid more per pound for calves than for yearlings because feed grains were so low in price that the feeder could add a pound of gain in the feedlot cheaper than he could buy it on the animal. High feed prices in 1974 together with lower beef prices reversed the situation.

The future of cattle prices is uncertain. It appears that the days of abundant cheap feed grains may be over. Also, as arable land shifts from feed crops to food crops, a higher percentage of the nation's beef will have to be produced from range forage and roughage. In any event, the relative advantages of cow-calf and cow-yearling operations can be estimated if the prices and weights of calves and yearlings are known. For example, if calves and yearlings sell for the same price per pound, the yearlings must weigh about 550 pounds to bring in as much as 400-pound calves (table 2). On the other hand, if the yearlings weigh 650 or more pounds they can sell for less per pound than calves and still produce more income. Computations in table 2

Table 5.--Break-even price for yearlings, compared to that for 400-pound calves sold in the fall

Weight of yearling (pounds)	Comparative price per pound for calves sold in fall				
	$0.25	$0.35	$0.45	$0.55	$0.65
	Break-even price for yearlings				
350	$0.40	$0.56	$0.71	$0.87	$1.03
450	.31	.43	.56	.68	.80
550	.25	.35	.45	.56	.66
650	.21	.30	.38	.47	.56
750	.18	.26	.33	.41	.48
850	.16	.23	.29	.36	.42
950	.15	.20	.26	.32	.38

assume yearly sale for cow-calf operations of 63 calves and 15 cull cows, plus 6 percent interest for 1 year on the sale value of the calf. For cow-yearling operations, the yearly sale would consist of 46 long yearlings and 11 cows.

Shifting from cow-calf to cow-yearling production reduces the number of animals marketed by about 27 percent. This could relieve the apparent oversupply of beef, reduce cattle inventories, and greatly reduce the amount of grain fed to beef cattle not only because fewer animals would be fed but because animals would enter the feed lot 200 to 400 pounds heavier.

Flexible or Constant Stocking

A major problem in making efficient use of forage is that production varies unpredictably from one year to the next. Grass yields may be as low as 60 or as high as 160 percent of the average. How can a rancher maintain a stable business in the face of such variations in forage yield? Is it better to adjust animal numbers to the forage crop each year, or should the range be stocked at a conservative but relatively constant rate?

One appeal of flexible stocking is that it allows more complete use of the forage in years of high production. This is commonly believed to increase ranch income, thereby offsetting low income and high expense in years of low production. Martin (1975), however, found that net sales per 100 animal units obtained by increasing stocking to 120, 130, or 140 percent of average in the best years were only $100 to $200 greater than for constant stocking at 90 percent of the level required for proper stocking in an average year. In practice, this small monetary advantage would probably be offset by the apparent disadvantages of the flexible system. These include the sheer difficulty of estimating forage crops and adjusting animals accordingly, possible serious damage to the range in years of low forage production when stocking is high due to high production the year before, the administrative costs of buying extra animals to stock the range in good years, the possibility of introducing parasites or disease with cattle from off the range, and the natural reluctance to cull as heavily as necessary for the good of the range in drought years. Constant stocking at 90 percent of average proper stocking appears to offer stability of operation, relatively high income, and moderate to low risk of damage to the range or financial crisis during drought. Even better for the range would be stocking at not to exceed 90 percent of average proper stocking, but with some reductions during prolonged severe drought.

Summary

Knowledge about managing livestock is generally adequate and readily available to the ranch operator. Furthermore, the direct economic importance of decisions in this field are so apparent to the rancher that he keeps abreast of developments on his own. Certainly the final answers to all questions about managing livestock are not yet in, but the priority of such questions for research by the Forest Service is quite low.

Correlating Grazing With Other Uses

Forage is a major product on semidesert range, and is marketed primarily through livestock. Other products of the range include water, timber, wildlife, and recreation.

Water and Wood

Semidesert ranges produce limited quantities of wood for fuel or for charcoal and fenceposts. Water yields from semidesert ranges likewise is relatively low, but the quality of water produced and the rate of runoff are greatly affected by grazing management. Well-managed ranges with a good cover of grasses yield water of higher quality and lower peak flood flows than do ranges with poorly dispersed cover. Good range management therefore is good watershed management. Likewise, removal of mesquite from semidesert ranges almost always improves forage production, ground cover, and water quality. Tree growth and forage growth apparently are competitive.

Surface water yield from ranges in good condition may be lower than on ranges in poor condition, but lower yield of water is offset to a degree by the higher quality. The yield of springs usually improves if brush is removed and better grass cover is established.

Wildlife

Most semidesert ranges support some wildlife. Desert mule deer, javelina, antelope, desert bighorn sheep, quail, doves, and rabbits are all hunted in season. Numerous nongame birds and animals, native to these ranges, are also becoming increasingly prominent in the public eye. Many semidesert ranges that once were almost pure grasslands now support moderate to dense stands of mesquite and other shrubs. The increased shrub cover has improved the habitat for deer and other wildlife; at the same time, forage production for livestock has decreased.

Near the eastern edge of the semidesert area in the Edwards Plateau region of Texas, ranchers now obtain a substantial part of their income from the sale of hunting privileges. Where the demands of urban sportsmen are great enough, a rancher may profitably manage his range to produce a mixture of wildlife and game if the vegetation on his range and the existing legal framework permit him to do so. In planning such a venture the rancher must consider many factors, including the relative effectiveness of grasses and shrubs for erosion control.

Recreation

Rangelands furnish an essential part of the recreational opportunities of the West. Desert outings during the spring flower season; off-road vehicle excursions; dude ranches, based on the perpetuation of the spirit of the Old West on a deluxe scale; concentrations of use by tourists in especially attractive canyons; and use in varying degree of an untold number of resorts and campgrounds are now common and will increase. The use of the range country for recreation seldom needs to interfere seriously with range livestock production.

Recreational use is beginning to become an important source of income in the range country. Many ranchers who formerly depended entirely on livestock for their income now supplement this with returns from dude ranching. On some ranches the recreational venture now dominates, and the livestock is little more than a feature to attract and entertain the guests. Recreational use promises to be a major factor in the social and economic life of the country.

Little is known of the relative compatibility of range livestock production with wildlife or recreation. The priority for research in this area is extremely high. Public land administrators need sound information on which to base decisions involving land-use conflicts. Land-use decisions are being questioned with increasing frequency and severity as more and more interest groups assert their views as to how semidesert ranges should be used.

Administrators of public rangelands must also be concerned with who pays the costs of management, improvement, and administration. The rancher pays grazing fees, the hunter or fisherman buys a license, and recreationists pay for the use of certain facilities. Many who enjoy the out-of-doors, however, pay nothing directly for the maintenance or improvement of the wide-open spaces they enjoy. The question of who pays for what needs to be answered, especially in cases where recreation replaces grazing as the dominant use.

Research in this field must deal with the entire ecosystem. A multidisciplinary program is needed not only to evaluate the impact of range management and improvement practices on forage, water, and wildlife, but to evaluate the impact of such practices on recreational opportunities.

RESEARCH RECOMMENDATIONS

Much semidesert range is producing far below its potential. Poor-condition ranges yield such hazards as flash floods and duststorms. More effective vegetative cover can improve the economic plight of ranchers and reduce offsite damage as well.

Properly managed ranges yield essential animal products at low cost for fossil energy without creating the additional problems of odor control and manure disposal that are associated with closely confined livestock. Those ranges also provide wildlife habitat and a variety of recreational values. A few lines of research that are needed to enhance the value of semidesert ranges to society are:

- Classify and develop readily comprehensible indices and standards of productivity for major semidesert range sites.
- Evaluate the impacts of alternative land treatments, and combinations of treatments and uses on such sites.
- Evaluate alternatives to continuous yearling grazing.
- Develop standards of utilization for major range sites that are compatible with such grazing systems.
- Identify and evaluate the beneficial effects of grazing.

• Evaluate the possibilities of prescribed burning in combination with other shrub control methods as a tool for manipulating semidesert vegetation.
• Evaluate the impacts on wildlife, scenic beauty, and other recreational amenities of programs designed to increase production of grass and beef.
• Evaluate the potential demand for and utilization of semidesert range for recreation.

SUMMARY AND CONCLUSIONS

The vegetation of much semidesert range has changed greatly since domestic livestock were introduced about 100 years ago. Generally, the change has been characterized by a reduction in perennial grasses and an increase in such shrubs as mesquite, creosotebush, and cactus. Although the quality of management has improved greatly on most semidesert ranges within the last two or three decades, the majority of semidesert range is producing less forage than it is capable of.

For at least 20 years, cattle ranching in the semidesert has not been highly profitable except when cattle prices were high. Ranches sell for about four times their value for range livestock production. Speculation in land based on the current southwestern land boom, and purchase of ranches by wealthy individuals, have contributed to the current high price of rangeland. Production ranchers cannot compete with consumption ranchers in bidding for ranch property. Still, grazing will continue to be the major use of most semidesert range.

Grazing during winter apparently is not harmful to perennial grasses, but grazing either in spring or summer if too frequent or too heavy will reduce the vigor and density of perennial grasses. From a livestock production viewpoint, yearlong grazing is an acceptable system for semidesert ranges, and generally does not result in severe depletion of the range resource if utilization does not exceed an average of about 40 percent. The deficiency of yearlong grazing is that uneven distribution of use from place to place and among species cannot be avoided. The only systems of grazing that have proved superior to yearlong conservative grazing are those that provide relatively long rest periods (from ⅓ to ⅔ of the total elapsed time) with rest during the spring and summer growing periods.

Acceptable procedures for seeding have been developed for ranges with annual precipitation of 13 inches or more. The success of seeding on drier ranges is less certain, but can be enhanced greatly by pitting to increase infiltration of rainwater. New seedings must be protected from grazing for at least one growing season; protection for two seasons is recommended.

Mesquite control has proven beneficial throughout almost all the semidesert area. Several mechanical and chemical control methods have been developed; each is peculiarly suited to certain situations. Progress on development of chemical control methods has been slowed by concern over environmental impacts. The average rancher with a mesquite-infested range can supply forage for additional cattle much more cheaply by controlling mesquite than by purchasing additional land. The value of controlling creosotebush, cactus, burroweed, and snakeweed is much less clear.

The use of fire as a tool for manipulating vegetation on semidesert range deserves further study. Fire is relatively effective against burroweed and cactus, but only moderately effective against creosotebush and mesquite. A problem with fires is that the kinds of fire that are effective against shrubs severely damage perennial grasses. Still there is a possibility that periodic burning, coordinated with an appropriate system of grazing, can be used to maintain a grasslike aspect once the initial stand of shrubs has been controlled by some other method.

Experimental applications of nitrogen have greatly increased herbage production of annual and perennial grasses in years of average or better-than-average summer rainfall. The economics, however, have not been determined. Also the possibilities of using small amounts of fertilizer to speed up range improvement and to improve distribution of use have not been adequately investigated.

Techniques of water development, fencing, salt placement, riding, trail construction, and so forth have been fairly well developed. Two relatively new developments in the field of water development are the horizontal well and the trick tank. These devices may assume more importance as the quality of range management improves and surface ponds become less effective.

Semidesert ranges provide a home for desert mule deer, javelina, and a variety of small animals and birds. In some cases the decline in productivity of semidesert range for livestock due to increases in shrubs has resulted in an increase in wildlife. The socio-economic climate now is such that maximum livestock forage is no longer an acceptable goal for all semidesert range. Instead, some pattern of vegetation that provides food and cover for wildlife as well as livestock may be more acceptable.

Poorly managed semidesert range contributes negative offsite values including dust, silt, and peak flood flows. A dense, well-dispersed perennial grass stand probably offers the best protection to the surface soil and minimizes these negative values.

Use of semidesert lands for hunting, hiking, rock hounding, birding, and related activities is increas-

ing. Off-road vehicle travel is another interest that poses a threat to the stability of semidesert soils. Recreation and livestock production need not necessarily compete. Increasing range livestock production may actually enhance recreation values by increasing the opportunities for recreationists to see range animals.

Urban people are taking an increased interest in what happens on semidesert rangelands, particularly those in public ownership. Much of the semidesert range near major population centers will eventually go into suburban housing or other nonrange uses. More remote parts of the range will be visited by hunters and recreationists, and will provide an opportunity for ranchers to develop a second source of income.

Range livestock production produces a usable product for society with little expenditure of fossil fuel. Range livestock are also produced without the problems of offensive odors and manure disposal problems characteristic of feedlots. Thus, range livestock production under good management practices has little or no adverse impact on the environment.

New research on semidesert range should emphasize: (1) classification, description, and evaluation of semidesert range sites, (2) evaluation of promising grazing systems, (3) evaluation of prescribed burning as a tool for maintaining desirable vegetation patterns, (4) evaluation of the impacts of range management practices on wildlife, scenic beauty, and other recreational attributes, and (5) evaluation of the current and potential demand for recreational use of semidesert range.

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COMMON AND BOTANICAL NAMES OF PLANTS MENTIONED

Common Name	Botanical Name
Perennial Grasses	
Alkali sacaton	*Sporobolus airoides* Torr.
Arizona cottontop	*Trichachne californica* (Benth.)
Black grama	*Bouteloua eriopoda* Torr.
Blue grama	*Bouteloua gracilis* (H.B.K.) Lag.
Blue panicum	*Panicum antidotale* Retz.
Boer lovegrass	*Eragrostis chloromelas* Steud.
Buffelgrass	*Pennesetum ciliare* (L.) Link.
Bush muhly	*Muhlenbergia porteri* Scribn.
Curly mesquite	*Hilaria belangeri* (Steud.) Nash
Green sprangletop	*Leptochloa dubia* (H.B.K.) Nees
Hairy grama	*Bouteloua hirsuta* Lag.
Johnsongrass	*Sorghum halepense* (L.) Pers.
Lehmann lovegrass	*Eragrostis lehmanniana* Nees
Mesa dropseed	*Sporobolus flexuosus* (Thurb.) Rydb.
Mixed gramas	*Bouteloua* spp.
Plains bristlegrass	*Setaria macrostachya* H.B.K.
Plains lovegrass	*Eragrostis intermedia* Hitchc.
Rothrock grama	*Bouteloua rothrockii* Vasey
Santa Rita threeawn	*Aristida glabrata* (Vasey) Hitchc.
Sacaton	*Sporobolus wrightii* Munro
Sand dropseed	*Sporobolus cryptandrus* (Torr.) A. Gray
Sideoats grama	*Bouteloua curtipendula* (Michx.) Torr.
Slender grama	*B. filiformis* (Fourn.) Griffiths
Sprucetop grama	*Bouteloua chondrosioides* (H.B.K.) Benth.
Tall threeawns	*Aristida hamulosa* Henr. and *A. ternipes* Cav.
Threeawns	*Aristida* sp.
Tobosa	*Hilaria mutica* (Buckl.) Benth.
Forbs	
Filaree	*Erodium cicutarium* (L.) L'Her.
Leatherweed croton	*Croton corymbulosus* Engelm.
Russianthistle	*Salsola kali* L.
Spectacle-pod	*Dithyrea wislizenii* Engelm.
Woolly paperflower	*Psilostrophe tagetinae* (Nutt.) Greene
Trees and Shrubs	
Acacias	*Acacia* sp.
Burroweed	*Aplopappus tenuisectus* (Greene) Blake
Catclaw acacia	*Acacia gregii* A. Gray
Cholla	*Opuntia* sp.
Creosotebush	*Larrea tridentata* (DC.) Coville
Fourwing saltbush	*Atriplex canescens* (Pursh) Nutt.
Juniper	*Juniperus* spp.
Mesquite	*Prosopis* spp.
Pricklypear	*Opuntia engelmannii* Salm-Dyck
Snakeweed	*Gutierrezia* spp.
Soaptree yucca	*Yucca elata* Engelm.
Tarbush	*Flourensia cernua* DC
Wait-a-bit (catclaw mimosa)	*Mimosa biuncifera* Benth.
Whitethorn	*Acacia constricta* Benth.

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The vegetation on much southwestern semidesert range has shifted from grassland to brush since livestock ranching began 100 years ago. Shrub control, reseeding, and improved grazing management have reversed the downward trend on some ranges but most ranges are producing below their potential. The role of ranges in meat production will become more important as increased population requires that arable lands be used mainly for food production.

Keywords: Semidesert range, grazing system, plant control, multiple use.

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Although this report discusses research involving pesticides, such research does not imply that the pesticide has been registered or recommended for the use studied. Registration is necessary before any pesticide can be recommended. If not handled or applied properly, pesticides can be injurious to humans, domestic animals, desirable plants, fish, and wildlife. Always **read** and **follow** the directions on the pesticide container.

PROTECT

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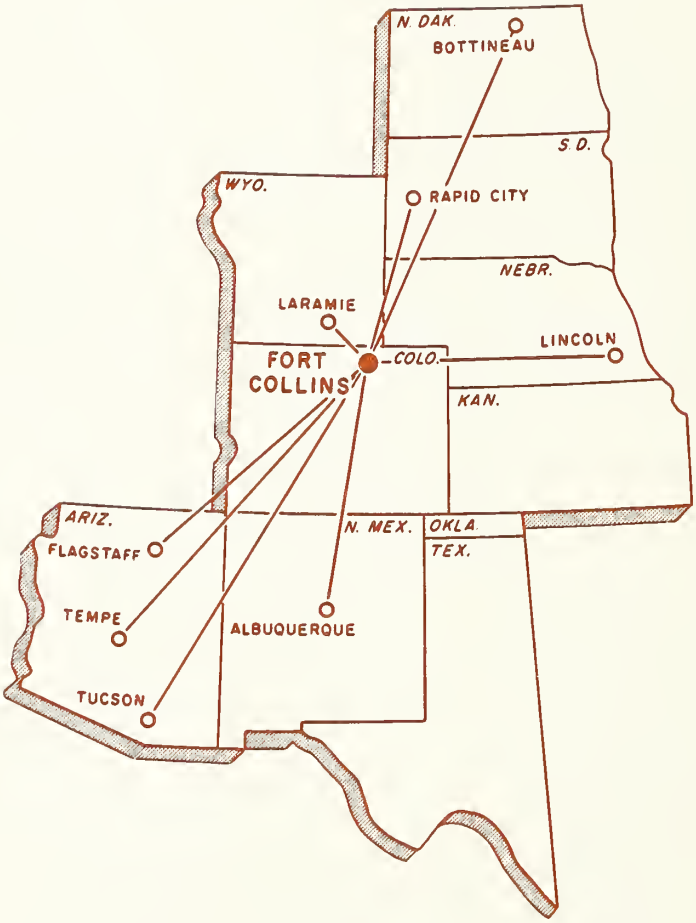
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